Geochemical Characterization of a Feeder-Dike System in the Seiland Igneous
Complex, Northern Norway: Implications for Geotectonic Environment of
Emplacement

by

Danielle E. Keathley, B.S.

A Thesis

In

Geosciences

Submitted to the Graduate Faculty
of Texas Tech University in
Partial Fulfillment of
the Requirements for
the Degree of

MASTER OF SCIENCES

Approved

Dr. Callum Hetherington
Chair of Committee

Dr. Calvin Barnes

Dr. Melanie Barnes

Mark Sheridan
Dean of the Graduate School

December, 2017

Copyright 2017, Danielle Keathley

ACKNOWLEDGMENTS

I would like to thank my advisor, Dr. Callum Hetherington for his incredible patience, guidance, and encouragement during my pursuit of my degree. I want to also thank him for the research environment that he has created- one that focuses on learning as well as building supportive friendships. The knowledge and experiences I have gained in this type of setting are immeasurable.

I would like to thank Dr. Cal Barnes for the preparedness his graduate courses provided, his open-door policy, and the multitude of conversations on igneous petrology and petrography that aided my research greatly. I am tremendously grateful for Dr. Melanie Barnes and her time spent teaching me not only to run instruments, but also providing understanding of how the instrumentation operates. Her instruction has been invaluable and her patience with a beginner appreciated.

I'd also like to thank my peer, Ethan Backus, for his overwhelming amount of help during my time at Texas Tech. His experience with the way things run and his willingness to provide support to those around him will always be appreciated. Lastly, I'd like to thank my family and friends for the endless amount of love and support I received while pursuing my academic goals.

TABLE OF CONTENTS

ACKNOWLEDGMENTS	ii
ABSTRACT.....	iv
LIST OF TABLES	vi
LIST OF FIGURES	vii
I. INTRODUCTION.....	1
II. GEOLOGIC BACKGROUND	4
III. METHODS	7
X-Ray Fluorescence (XRF)	7
Scanning Electron Microscopy (SEM)	9
Laser Ablation Inductively Coupled Mass Spectrometry (LA-ICPMS).....	9
IV. RESULTS.....	12
Sample Selection.....	12
Petrography	13
Whole Rock Compositions	20
Trace Element Abundances in Minerals	36
V. DISCUSSION	43
Crystal Accumulation	43
Tectonic Discrimination.....	46
Alkaline Rocks in Wilson Cycles	54
Temperature and Pressure.....	57
VI. CONCLUSIONS.....	60
REFERENCES.....	62
 APPENDICES	
A. APPENDIX A	71
B. APPENDIX B.....	78

ABSTRACT

The 575-560 Ma Seiland Igneous Province is an intrusive suite of mafic and ultramafic rocks, occasional monzonites and diorites, and, carbonatite and (nepheline)-syenite alkaline dikes on the northwest margin of Baltica that have a contested geotectonic origin. The carbonatite and alkaline magmas were used to argue for a rift environment, but such magmatism may occur in back-arc basins or during de-suturing of a continent-continent boundary. Another source of complexity is that many rocks are cumulates with modified geochemical signatures that makes application of compositional-based discrimination techniques challenging. A suite of mafic-ultramafic, monzodiorite and nepheline monzonite dikes that may represent a feeder system to structurally higher plutons were sampled on the island of Sørøy. They were geochemically analyzed and the data used to test compositional-based models for geotectonic environments of emplacement.

Geochemically, with increasing SiO_2 , the rocks have increasing Al_2O_3 , Na_2O , and K_2O with decreasing TiO_2 , Fe_2O_3 , MgO , CaO , and P_2O_5 , and are enriched in Sr, Ba, and Rb relative to N-MORB. Some high-field strength elements (Th, Ta, Nb) are enriched by factors of 10 to 100 compared to N-MORB, while others (Zr to Yb) have values closer to unity or less. Chondrite normalized whole-rock REE patterns are LREE enriched and the mafic to ultramafic samples have consistently negative REE slopes, although HREE slopes flatten and turn slightly positive as silica content increases. All samples have

positive Eu anomalies that increase in magnitude from ultramafic to mafic through the nepheline monzonites. Chondrite normalized REE patterns for amphibole in the mafic to ultramafic samples have flat or slightly positive sloped LREE patterns that become negative from MREEs to the HREEs. Trace element geochemistry reflects increasing Ce/Yb, Th/Yb, and Ta/Yb ratios with increasing alkalinity and SiO₂ content. Pearce discrimination diagrams show that many of the dikes are compositionally similar to within-plate basalts.

The geochemical data, coupled with geochronology and paleogeographic reconstructions, are used to argue that emplacement of the Seiland Igneous Province occurred during de-suturing of Rodinia along the Lapland-Kola Suture during the earliest stages of the opening of Iapetus.

LIST OF TABLES

3.1	Precision and accuracy of XRF analyses of standards.....	8
3.2	Precision and accuracy of LA-ICPMS of standards	11
4.1	Rock descriptions for Seiland samples	13
5.1	Calculated pressures for Seiland samples	59

LIST OF FIGURES

1.1	Map of Norway and the Seiland Igneous Province.	3
4.1	Field sketch and photograph of sample location.....	12
4.2	Photomicrographs for mafic to ultramafic samples	17
4.3	Photomicrographs for monzodiorite samples	19
4.4	Photomicrographs for nepheline monazite sample	20
4.5	Total alkali silica diagram.....	21
4.6	Modified alkali-lime index diagram	22
4.7	Major element Harker variation diagrams	24
4.8	Trace element Harker variation diagrams.....	25
4.9	Major element and Mg # variation diagrams	27
4.10	Trace element and Mg # variation diagrams.....	28
4.11	Whole-rock chondrite-normalized REE patterns.....	29
4.12	Whole-rock N-MORB normalized spider plots	29
4.13	Zr/Y and Ti/Y tectonic discrimination diagram.....	31
4.14	Ti/Y and Nb/Y tectonic discrimination diagram	31
4.15	Zr/Y and Zr tectonic discrimination diagram	32
4.16	K ₂ O/Yb and Ta/Yb tectonic discrimination diagram.....	34
4.17	Ce/Yb and Ta/Yb tectonic discrimination diagram	35
4.18	Th/Yb and Ta/Yb tectonic discrimination diagram	36
4.19	Chondrite normalized REE plots for Seiland amphiboles	38
4.20	Bivariant diagrams showing trace element variation in amphiboles	41
4.21	Bivariant diagrams highlighting Nb and Ti variation in amphiboles	42
5.1	Ni, Cr, and Al ₂ O ₃ behavior in mafic & ultramafic samples.....	45
5.2	N-MORB normalized spider plots for rocks from rifts and back-arcs	47
5.3	N-MORB normalized spider plots for rocks from rifts, back-arcs, and SIP rocks	48
5.4	Chondrite normalized REE plots for rocks from rifts and back-arcs.....	49

5.5	Chondrite normalized REE plots for rocks from rifts, back-arcs, and SIP rocks	50
5.6	Harker variation diagrams for rocks from rifts, back-arcs, and Seiland samples.....	53
5.7	Illustration on how ARCs and DARCs are formed	56
5.8	Geologic map of the island of Sørøy, Northern Norway	56
5.9	Paleogeographic reconstructions	57

CHAPTER I

INTRODUCTION

The Seiland Igneous Province is an intrusive suite of mafic and ultramafic units, occasional monzonites and diorites, and a suite of carbonatite and (nepheline)-syenite alkaline dikes on the northwest margin of Baltica (Figure 1.1). The origins of the Province are somewhat enigmatic because, although the existence of carbonatite-to-alkaline magmas indicates an extensional tectonic regime (Burke et al., 2007), there is some debate over whether it was emplaced into a back-arc basin, a rift-setting, or along the Lapland-Kola Suture during the earliest stages of the opening of Iapetus (Burke et al., 2007). The presence of carbonatite and alkaline rocks in the Seiland Igneous Province (SIP) have been used to argue for a continental rift environment (Jones et al., 2013). However, alkaline rocks are also found in a variety of other extensional regimes associated with subduction and collisional environments (Hoernle et al., 2002; Hou et al., 2015; Hou et al., 2006). The short period of time in which Seiland Igneous Province magmatism occurred (~15 Ma) (Roberts et al., 2006; Roberts et al., 2010) suggests that an extensional environment is most likely, as opposed to a longer-lived back-arc system that would be associated with subduction-related tectonics. This timeline is also compatible with the proposal that the area must have been affected by the breakup of Rodinia (Li et al., 2008).

Distinguishing between these extensional environments, particularly using geochemical methods is challenging. Notable characteristics of back arc basins include the enrichment of large ion lithophile elements (LILEs; (Gill, 1976), however, a rift environment may produce a similar geochemical signature if crustal material is incorporated (Furman, 2007). On the other hand, differentiating between the two environments may be possible through the study of high field strength elements (HFSE). A decrease in HFSEs paired with the increase in LILEs relative to MORB would be more indicative of a back arc basin (Gill, 1976), whereas a continental rift would have less LILE enrichment and HFSE depletion (Furman, 2007). Another challenge to the study of large igneous complexes using whole-rock geochemical techniques, particularly in mafic-dominated systems, is the impact of crystal accumulation on geochemical signatures (Barnes et al., 2016a; Naslund and McBirney, 1996; Wagner and Brown, 1968). As such, the few attempts to characterize the tectonic origins of the Seiland Igneous Province have not been conclusive (Corfu et al., 2007).

To address the complexity introduced by cumulate rocks, a suite of dikes that may represent feeder systems to structurally higher plutons was sampled on the island of Sørøya (Figure 1) and have been described and characterized, using a combination of whole-rock and mineral-geochemistry. The geochemistry of rocks from these samples is then compared to examples of similar rocks from well characterized tectonic environments. The different tectonic settings produce prominent discrepancies in their whole-rock geochemistry, which is compared to the Seiland data. Conclusions based on

bulk-rock compositions are further tested by analyzing trace element signatures in amphibole and pyroxene, which are increasingly recognized as capable of preserving evidence of trends and processes in magmatic systems (Barnes et al., 2016b; Barnes et al., 2016c; Coint et al., 2013).

Fig. 1.1. (a) Map of Norway with the location of the Seiland Igneous Province marked by a box (Roberts et al., 2006). (b) Geologic map of the Seiland Igneous Province (Roberts et al., 2010). Sample location represented by the red X at approximately 70°33'13.6"N, 22°15'11"E.

CHAPTER II

GEOLOGIC BACKGROUND

The Finnmark region in northern Norway displays evidence of multiple orogenic events (Roberts et al., 2006). Three separate deformational events (D1, D2, and D3) were recognized by (Ramsay et al., 1985). The first deformational event (D1) was identified based on a poorly preserved widespread schistosity in the Sørøy Group (Roberts et al., 2006; Sturt et al., 1978; Sturt et al., 1975). The second and most prominent deformational event (D2) was interpreted to form during the Finnmarkian Orogeny (490-540 Ma) (Ramsay et al., 1985; Sturt et al., 1978; Sturt et al., 1975), evidence of which is displayed as folds, foliations, and metamorphism (Roberts et al., 2006). These folds and foliations were reoriented during the Scandian phase of the Caledonian Orogeny (~420 Ma), which represents the third and final deformational event (D3; (Roberts et al., 2006).

Assessing the validity of the D1-D3 events has long been problematic due to the presence of correlating deformation signatures across much of the area (Roberts et al., 2006). A more recent study recognized the existence of comparable structures that developed at different locations in Finnmark during totally unrelated events that range in age from Precambrian to Silurian. Daly et. al. (1991) dated various igneous intrusions using a variety of isotopic methods (Rb/Sr, Sm/Nd, U/Pb) to demonstrate that D2 deformation of the Klubben Psammite took place before 800 Ma. The resulting model

questioned the existence of the Finnmarkian Orogeny and proposed a 250 m.y. period in the Precambrian during which rifting took place (Daly et al., 1991). Such a long period of rifting seems unusual and would need to call on both extension and contraction to cause episodic emplacement.

The 575-560 Ma Seiland Igneous Province (SIP) was intruded into Sørøy Group metasedimentary rocks, which are part of the Kalak Nappe (Roberts et al., 2006). Emplacement of the SIP occurred during the D2 event and before D3 deformation (Daly et al., 1991). The plutons are mostly gabbroic and display a wide variety of geochemical signatures ranging from calc-alkaline to tholeiitic to alkaline (Robins, 1996; Robins and Gardner, 1975). A small amount of coeval felsic to intermediate material, including monzonites and diorites, both intrude and are intruded by the gabbroic plutons (Roberts et al., 2006). Ultramafic rocks such as pyroxenite and hornblendite cut the plutons of the province, and contain a significant amount of xenoliths from these plutons (Roberts et al., 2006). Though these ultramafic plutons must be younger than the mafic plutons they crosscut, they exhibit the same metamorphic and D3 deformation signatures (Bennett et al., 1986) which are interpreted to be a result of Scandian metamorphism near the end of the Caledonian Orogeny (Corfu et al., 2014; Sturt and Ramsay, 1965). U-Pb dating of zircon and titanite indicates that magmatism in the Seiland Igneous Province was initiated at 574 ± 5 Ma by emplacement of a carbonatite, followed by mafic/ultramafic magmatism then syenite magmatism, the majority of which occurred by ~560 Ma (Roberts et al., 2010), although there is evidence for syenite dike intrusion at ~520 Ma

(Pederson et al., 1989). Zircons associated with unrelated magmatism in the Helgeland Nappe Complex have an age of 520-490 Ma (Barnes et al., 2007). The late (~520 Ma) syenite dike intrusion thought to represent the end of Seiland emplacement is more likely to be associated with the unrelated magmatism in the Helgeland area.

The Silurian collision between the continents of Baltica and Laurentia (Torsvik et al., 1996) caused the formation of the Scandinavian Caledonian thrust belt (Gayer et al., 1985). During final development of the thrust belt, between 420 and 400 Ma, multiple Eocambrian to Cambrian allochthonous nappes were thrust onto older Precambrian basement and unconformable sedimentary cover (Stephens and Gee, 1989). Within the group of thrust material, a major, relatively thick complex named the Kalak Nappe Complex overlies the smaller subordinate Laksefjord and Gaissa Nappes (Holtedahl and Dons, 1960; Roberts et al., 2010). A basal layer of banded rocks, which can be comprised of orthogneiss, paragneiss, or a combination of the two, makes up the foundation of each nappe in the Kalak Nappe Complex (Ramsay et al., 1985; Roberts et al., 2006; Sturt et al., 1978). The basal layers are capped by a metasedimentary cover (Roberts et al., 2006). The Sørøy Nappe is the uppermost nappe in the complex and is intruded by the igneous rocks that make up the Seiland Igneous Province (Cadow, 1993), both of which were transported from the margin of Laurentia to Baltica during the Scandian phase of the Caledonian Orogeny (Ramsay et al., 1985; Roberts, 2003). After suturing of Baltica and Laurentia, the continents separated to form the Northern Atlantic Ocean (Kovalenko et al., 2010).

CHAPTER III

METHODS

X-Ray Fluorescence (XRF)

Samples for whole rock geochemical analysis were prepared by crushing, powdering, and glass disc fusion. Rock crushing was completed using large and small jaw crushers. An alumina shatterbox was used to powder the crushed rocks. Once powdered, the samples were tested for loss on ignition (LOI) by placing a measured amount of powdered sample into preheated crucibles. The crucibles were held at 1000°C in an oven for thirty minutes. After cooling in a desiccator the samples were weighed to determine the amount of volatiles lost.

The LOI powder was fused to create glass discs. Before fusing 1.2000g $\pm$ 0.0010g of LOI powder was mixed with 4.8000g $\pm$ 0.0020g of a 49.75% Li-metaborate, 49.75% Li-tetraborate, and 0.5% LiBr fluxing agent. The mixture was placed in a platinum crucible along with 40 μ l of LiI wetting agent, followed by fusing in a Claisse M4 fluxer.

Analysis by XRF was done at Texas Tech University using a Thermo Scientific ARL Perform 'X' instrument. Elements (ppm) and oxides (wt %) collected include Al₂O₃, Ba, CaO, Cr, Cu, Fe₂O_{3(TOT)}, K₂O, MgO, MnO, Na₂O, Ni, P₂O₅, SiO₂, Sr, TiO₂, V, Zn, and Zr. Elements were analyzed at 60 kV and 60 mA except for Al₂O₃, MgO, Na₂O, P₂O₅, and SiO₂ which was analyzed at 30 kV and 120 mA.

Precision and accuracy were measured by analyzing standards (AGV, SDC, TLM, W-2, ASK, SCO, and MAG) before, during, and after sample analyses. Standard deviation percent and percent error of the average composition of each standard are presented in Table 3.1.

Table 3.1: Precision and Accuracy of XRF Analyses of standards

	AGV (n=2)	SDC (n=4)	TLM (n=4)	W-2 (n=4)	ASK (n=4)	SCO (n=4)	MAG (n=4)
Precision							
<0.1%	Al ₂ O ₃ , CaO, Fe ₂ O ₃ , K ₂ O, P ₂ O ₅ , SiO ₂	Al ₂ O ₃ , CaO, K ₂ O, SiO ₂	Al ₂ O ₃ , CaO, Fe ₂ O ₃ , K ₂ O, SiO ₂	Al ₂ O ₃ , CaO, K ₂ O, MgO, SiO ₂	Al ₂ O ₃ , Fe ₂ O ₃ , K ₂ O, Na ₂ O, SiO ₂ , TiO ₂	CaO, K ₂ O, SiO ₂	Al ₂ O ₃ , Fe ₂ O ₃ , K ₂ O, SiO ₂ , TiO ₂
0.1-0.5%	MgO, MnO, Na ₂ O, TiO ₂	Fe ₂ O ₃ , MgO, MnO, Na ₂ O, P ₂ O ₅ , TiO ₂	MgO, MnO, Na ₂ O, P ₂ O ₅ , TiO ₂	Fe ₂ O ₃ , MnO, Na ₂ O, P ₂ O ₅ , TiO ₂	CaO, MgO	Al ₂ O ₃ , Fe ₂ O ₃ , MgO, P ₂ O ₅ , TiO ₂	CaO, MgO, MnO, Na ₂ O, P ₂ O ₅
>0.5%					MnO	MnO, Na ₂ O	
Accuracy*							
<5%	Al ₂ O ₃ , CaO, Fe ₂ O ₃ , K ₂ O, MgO, Na ₂ O, P ₂ O ₅ , SiO ₂ , TiO ₂	Al ₂ O ₃ , CaO, K ₂ O, MnO, Na ₂ O, SiO ₂ , TiO ₂	Al ₂ O ₃ , CaO, Fe ₂ O ₃ , K ₂ O, MgO, Na ₂ O, SiO ₂ , TiO ₂	Al ₂ O ₃ , CaO, Fe ₂ O ₃ , K ₂ O, MgO, MnO, Na ₂ O, P ₂ O ₅ , SiO ₂ , TiO ₂	Al ₂ O ₃ , CaO, Fe ₂ O ₃ , K ₂ O, MnO, Na ₂ O, SiO ₂	Al ₂ O ₃ , CaO, K ₂ O, MgO, Na ₂ O, P ₂ O ₅ , SiO ₂	Al ₂ O ₃ , CaO, K ₂ O, MgO, MnO, P ₂ O ₅ , SiO ₂ , TiO ₂
5-8%	MnO	P ₂ O ₅ , MgO	MnO, P ₂ O ₅		MgO, TiO ₂	MnO, TiO ₂	Na ₂ O
>8%		Fe ₂ O ₃					Fe ₂ O ₃

*Accuracy given as percent uncertainty

Scanning Electron Microscopy (SEM)

Polished thin sections were coated with iridium conductive coating and the electron microscope was operated with an accelerating voltage of 15 kV. Back scatter electron images on individual mafic phases were taken with the Hitachi S4300VP at Texas Tech College of Arts and Sciences Electron Microscopy Facility. The back scattered electron (BSE) emission intensity is dependent on the average atomic number of the sample (Putnis, 1992). This dependency introduces compositional variations in the contrast of the image due to localized atomic number differences, which can be used to map domains within individual minerals. Major element compositional data was obtained by SEM through Energy Dispersive X-Ray Spectroscopy (EDS). Mineral chemistry was quantified using an EDAX Pegasus 4040 Energy Dispersive Spectrometer (EDS) with EDAX Genesis software used to collect and quantify the data.

Laser Ablation Inductively Coupled Mass Spectrometry (LA-ICPMS)

The glass discs used in XRF analysis were cut and polished for trace element analysis by laser ablation inductively coupled mass spectrometry (LA-ICPMS) in the GeoAnalytical Laboratories at Texas Tech University. Polishing was completed using 1 μm diamond paste on a Beuhler Beta polisher. Analyses were conducted using an Agilent 7500cs quadrupole mass spectrometer with a New Wave UP-213 solid state laser. Laser conditions included an 80 μm spot size, 10 Hz pulse rate, and laser energy from 10.05 to 12.83 J/cm^2 . Elements analyzed were Na, Mg, Al, Si, Ca, Sc, Ti, V, Ga, Rb, Sr, Y, Zr,

Nb, Ba, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Er, Yb, Lu, Hf, Ta, Pb, Th, and U. All elemental data collected during LA-ICPMS are given in ppm. Data reduction was performed using an Excel spreadsheet supplied by Australian National University. The calibration standard was USGS GSD glass and USGS standard BHVO-2G was analyzed 3-4 times each session as an external measure of precision and accuracy. The internal element standard for each disc was the calcium abundance determined by XRF analysis.

Polished thin sections for each sample were prepared for individual mineral trace element analysis by LA-ICPMS that was conducted within the same laboratories at Texas Tech University. Polishing was completed using 9, 3, and 1 μm diamond pastes using a Beuhler Beta polisher. Spots locations were determined on the basis of zoning identified in optical and BSE images. Laser conditions were 40 μm spot size, 5 Hz pulse rate, and 8.10 to 9.89 J/cm^2 laser energy. Elements analyzed were Mg, Al, Si, P, Ca, Sc, Ti, V, Cr, Mn, Fe, Ni, Cu, Rb, Sr, Y, Zr, Nb, Mo, Ba, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Hf, Ta, Th, and U. All elemental data collected during LA-ICPMS are given in ppm. Data reduction followed the method used for glass discs, except that the calibration standard was NIST 612 glass. USGS standard BHVO was also analyzed 3-4 times each session as an external measure of precision and accuracy. The internal element standard for each grain was the calcium abundance determined by EDS analysis, except for samples in which the calcium abundance was below detection limits. In these cases the SiO_2 value was used as the internal standard.

Precision and accuracy were measured by analyzing the USGS BHVO standard before, during, and after sample analyses. Standard deviation percent and percent error of the average composition of each standard are presented in Table 3.2

Table 3.2: Precision and accuracy of LA-ICPMS of standards

BHVO (n=11) The	
Precision	
< 2%	Sc, Nd, Ta
2-4%	Y, Zr, Nb, Ba, La, Ce, Sm, Gd, Tb, Hf, Th
<4%	V, Rb, Sr, Yb, Lu
Accuracy*	
<5%	Ba
5-15%	Sc, V, Rb, Nb, La, Ce, Nd, Sm, Gd, Tb, Yb, Hf, Th
>15%	Sr, Y, Zr, Lu, Ta
*Accuracy given as percent uncertainty	

CHAPTER IV

RESULTS

Sample Selection

Samples were collected from the island of Sørøy on a wave-cut platform on the south shore of Brevikbotn (Figure 1.1b). The sampled dikes have well constrained cross-cutting relationships (Fig. 4.1) that may be used to build a relative timeline for dike emplacement. Table 4.1 provides sample names and descriptions for samples numbered as in the sketch and photograph.

Fig. 4.1. Field sketch and corresponding photograph of the sample area. Originally sketched by Callum Hetherington. Sampled sections are numbered and the numbers correspond with table 4.1. The depth of the section is 25 m.

Table 4.1 Rock Descriptions

	Sample Number	Rock Name; Description
1	RJR 238	Hornblendite; Coarse grained, dark, no foliation
2	RJR 239	Hornblendite; Collected from bulging section of outcrop, band is almost elongate pillow like, friable and ropey like. Brown oxidized areas possibly altered olivine
3	RJR 240	Hornblendite; Small sample, coarse grained gabbro, very friable
4	RJR 241	Gabbro; Lighter grey. 50% black 50% white material, metamorphic rock. Equigranular. This rock has a mafic dyke which predates 3 and 5
5	RJR 242	Hornblendite; Fine grained to medium grained dark rock. Fine grained areas represent chilled margins.
6	RJR 243	Gabbro; See 241. This sample is much more friable.
7	RJR 244	Monzodiorite; Fine grained grey early alkaline dyke.
8	RJR 245	Monzodiorite; Youngest dyke in the complex. White/tan coarse grained with blebs of biotite
9	RJR 246	Nepheline Monzonite; Alkaline gneiss. Little apparent internal mineral lineation. White rock with black biotite bands
10	RJR 247	Hornblendite; Lineated ridges of rock from close to junction between veins. Sampled what is hopefully earlier dyke. Fine grained, overall dark. 70% black, 30% white.

Petrography

RJR 238-1

Sample 238-1 is a hornblendite consisting of 80 vol.% of 0.6-1.5 mm yellow-brown amphibole with opaque inclusions. The majority of the opaques are concentrated within the cores of crystals, whereas others form patches within the grains. Biotite occurs in small, heterogeneously distributed clusters that make up ~ 3 vol.% of the sample.

Biotite crystals range from 0.15 to 0.6 mm in size and have a tabular habit. Interstitial potassium feldspar (5 vol.%) and scapolite (~6 vol.%) occur within the sample. The scapolite was confirmed by EDS analysis, which identified peaks for Ca and Cl. Plagioclase (1-2 vol.%) and titanite (2 vol %) are accessory phases.

RJR 239

Brown amphibole is abundant (70 vol.%) and occurs as 1-1.3mm grains that display alteration to pale green amphibole, possibly actinolite, and biotite along some cleavage planes. Inclusions in the amphibole are apatite (~2 vol.%). Biotite (15 vol.%) occurs as 0.3-1.5mm long tabular grains that are reacting to chlorite around rims and along cleavage planes. Some biotite crystals are bent. Anhedral grains of olivine (0.5-1.5mm) are present (10 vol.%) and show red/brown alteration along fractures. Some of the olivine is completely replaced by the red/brown phase, which is identified as iddingsite. Apatite (3 vol.%) is present as small (0.15-0.3mm) anhedral grains.

RJR 240-3

Sample 240-3 is hornblendite with ~90 vol.% amphibole that may be subdivided into two populations. One population is pale yellow-brown-green and is distinctly pleochroic, whereas the other is dark green and weakly pleochroic. All amphibole crystals are anhedral but the two groups also differ in size. The dark green group ranges from 0.7-1.5 mm whereas the pale group ranges from 0.15-0.3mm. Opaque inclusions are very abundant within the amphibole, locally becoming so dense that the amphibole is not

visible. There are small amounts of interstitial calcite (3 vol.%), and apatite (5 vol.%) is present as inclusions within the amphibole. Some amphibole crystals have small (<1 vol.%) amounts of biotite flakes included within them. Anhedral plagioclase (~2 vol.%) measuring 0.075-0.15 mm long also occurs as an interstitial phase.

RJR 241-3

Sample 241-3 is classified as a gabbro based on the occurrence of plagioclase feldspar (35 vol.%), amphibole (40 vol.%), and augite and orthopyroxene (5 vol.%). Interstitial plagioclase crystals reach 3 mm in length. The pyroxenes occur as complex intergrowths/merged crystals/overgrowths, and their grain size is estimated to be 0.3-1.5 mm. The pyroxene is also heavily altered and difficult to distinguish from the amphibole. Locally the augite is replaced by amphibole, giving a “wavy” texture (Fig. 4.2, G). Opaque inclusions occur in about half of the pyroxene/amphibole crystals. Some of these pyroxene/amphibole grains display well developed rims that are a different color than the rest of the grain. Olivine (8 vol.%) occurs as highly fractured and highly altered inclusions in pyroxene. There are small amounts of biotite (5 vol.%) and chlorite (3 vol.%), some of which are deformed. Anhedral apatite is present in amounts of ~4 vol.%.

RJR 242-5

Sample 242-5 is a hornblendite that consists of 75 vol% yellow-brown-green pleochroic amphibole (75 vol.%). The sample is equigranular with equant, anhedral amphibole crystals that are about 0.6 mm in size. There are small amounts of interstitial

plagioclase (8 vol.%), white mica (5 vol %), and nepheline (5 vol.%), as well as apatite (4 vol.%) and titanite (1 vol.%). Many amphibole grains contain inclusions of 0.05-0.1 mm tabular biotite which make up 2 vol.% of the section.

RJR 243

Sample 243 is a gabbro and is similar to sample 241. There are large clusters of plagioclase that make up 30 vol.% of the sample, some grains display deformed twin planes. These plagioclase crystals are interlocking with one another and completely fill the interstitial space in the sample. The pyroxene is anhedral, highly altered, and ranges in size between 1.5 and 2 mm. The majority of the pyroxene is augite (35 vol.%), with small amounts of orthopyroxene (15 vol.%). Locally, the augite is rimmed by orthopyroxene. Opaque sulfides and silicates are so dense that they cover the pyroxene crystals, sometimes completely and other times in a patchy fashion. Within the pyroxenes there are inclusions of highly fractured olivine (10 vol.%) being replaced by iddingsite. The hornblende is interstitial and makes up 5 vol.% of the sample. Some augite has the same wavy texture found in sample 241, indicating replacement by amphibole. Small sphene crystals make up ~3 vol.% of the section. One small fragment of biotite is present (<1 vol.%).

Fig 4.2. Photomicrographs for the Seiland mafic to ultramafic samples. Photos are labeled with the letters A-F, which correspond to samples RJR 238-243. Photo G is an additional photomicrograph of sample RJR 241, provided to show a discussed texture. All photos were taken at 4x magnification and each scale bar represents 500 μm .

RJR 244

This sample is monzodiorite with anhedral 0.15-0.4 mm plagioclase feldspar (50 vol.%) and potassium feldspar (10 vol.%). Dark green to black and brown biotite crystals (25 vol.%) are distributed throughout the rock. Some biotite is tabular, whereas the remainder are anhedral flakes. The euhedral to subhedral tabular biotite ranges from 0.08 mm to 0.25 mm in length, whereas the flakes are anhedral and range in size from 0.015 to 0.3 mm in size. Interstitial white mica (5 vol.%) ranges from 0.05 mm to 0.15 mm. Titanite and apatite comprise 5% and 3% of the sample, respectively. Rare occurrences of red iron oxides are present in <1 vol.% of the sample.

RJR 245

Sample 245 is monzodiorite consisting of ~65 vol.% anhedral plagioclase feldspar (An₆₀) that ranges in size from 0.075 mm to 0.5 mm. These crystals interlock with potassium feldspar (15 vol.%), which is also anhedral and measures between 0.1 and 0.5 mm. Approximately 5 vol. % of the section is relict dark green hornblende that shows significant evidence of resorption, or perhaps breakdown during later greenschist metamorphism. Another 5 vol.% of the sample is opaque minerals that occur with small amounts of biotite (1 vol. %) and are located near groups of opaque minerals. The sample also contains interstitial white mica (2 vol.%), apatite (1 vol. %), and titanite (3 vol. %). Large crystals (~0.15mm) of titanite are intergrown with the amphibole,

elsewhere in the section the crystals are much smaller. Five to seven allanite crystals (1 vol.%) are intergrown and restricted to one area. The allanite crystals are red-brown to yellow brown anhedral grains that range in size between 0.2 and 0.3 mm and are slightly-moderately pleochroic. The yellowing of the allanite indicates the beginning of metamictization. Calcite crystals (1 vol.%) range in size between 0.15 and 0.2 millimeters. Less than 1 vol.% rutile is included in amphibole and calcite.

Fig. 4.3. Photomicrographs for the Seiland monzodiorites samples. Sample 244 is represented by letter A and sample 245 by letter B. scale bar represents 500 μm .

RJR 246

Sample 246 contains 55 vol% plagioclase feldspar which is anhedral and measures between 0.08 and 0.7 mm. Microcline was identified based on presence of grid-twinning (cross-hatch) and makes up 20 vol.% of the sample. The sample also contains 10 vol.% nepheline, which is evenly distributed throughout the sample as 0.05-1 mm crystals. Small amounts of mica are present (10 vol.% biotite and 2 vol.% white mica),

which are oriented in a weak foliation. The micas are tabular and range from 0.01 mm to 0.04 mm in length. Additional minerals include apatite (2 vol.%) and zircon (1%). This sample is classified as a nepheline monzonite with gneissic banding.

Fig. 4.4. Photomicrographs for the nepheline monzonite. Both photos are of sample 246. Photo A is in plane polarized light and B in cross polarized light. Photos were taken at 4x magnification and each scale bar represents 500 μ m.

Whole-Rock Compositions

Bulk compositions of samples from the Seiland Igneous Province are plotted in figures 4.5 through 4.15. The Seiland rocks are alkaline (Fig. 4.5), with the mafic to ultramafic rocks with the least alkaline characteristics. The monzodiorites have a slightly higher alkali content than the mafic rocks, whereas the separation between monzodiorites and the nepheline monzonite is more substantial. Mafic to ultramafic samples from the Seiland Province plot across the fields separating calcic, calc-alkalic, and alkali-calcic

(Fig. 4.6). The more felsic monzodiorites and nepheline monzonite are clearly separated from the mafic samples, plotting well into the alkalic field.

Fig. 4.5. Total alkali vs. silica diagram for the mafic to ultramafic rocks (red circles), monzodiorites (blue squares), and nepheline monzonite (green triangles) of the Seiland Igneous Province. The alkaline/subalkaline or tholeiitic boundary is taken from Macdonald 1968.

Figure 4.6. Modified alkali-lime index (MALI) diagram modified from (Frost et al., 2001). MALI is defined as $\text{Na}_2\text{O} + \text{K}_2\text{O} - \text{CaO}$. Solid lines are drawn separating field for alkalic (a), alkali-calcic (a-c), calc-alkalic (c-a), and calcic (c). Dashed lines are projections that assume the original lines continue. Mafic to ultramafic rocks are represented by red circles, monzodiorites by blue squares, and nepheline monzonite by the green triangle.

The whole-rock major element compositions reflect the mineralogical based discrimination with the mafic and ultramafic samples having lower SiO₂ and the monzonites and nepheline monzonites having higher SiO₂ abundances (Fig. 4.7). Well-defined trends are observed in some graphs (TiO₂, Al₂O₃, Fe₂O₃, Na₂O), while others have higher variance in their trends. The mafic and ultramafic samples contain higher TiO₂, Fe₂O₃, MgO, and CaO, whereas the more felsic rocks higher LILE abundances (Na, K). The felsic samples also contain a large amount of Al₂O₃ relative to the mafic and ultramafic samples. The nepheline monzonite is distinguished from the monzodiorites by

its higher Na_2O , and slightly higher K_2O . Abundances of P_2O_5 are high at low-silica levels and drop as silica levels increase, which coupled with the decreasing abundances of apatite observed in thin section, indicates the fractionation of apatite. The presence of larger percentages of apatite in the mafic and ultramafic rocks relative to the more evolved monzodiorites and nepheline monzonite supports the idea of fractional crystallization. The trend also presents widely differing P_2O_5 values for rocks at similar silica contents.

The trace element data for the Seiland rocks show a decrease in Ni, Cr, Sc, and V with increasing SiO_2 (Fig. 4.8). Vanadium and Sc are notable for their constant negative slopes. Barium displays a slight decrease with increasing SiO_2 in the mafic samples, paired with extreme enrichment in the more felsic samples, especially the monzodiorites. The mafic to ultramafic rocks have consistently low Sr and Zr abundances; greater abundances of these elements were documented in the monzodiorites and nepheline monzonite.

Fig. 4.7. Harker variation diagrams for mafic to ultramafic rocks (red circles), monzodiorites (blue squares), and nepheline monzonite (green triangles) from the Seiland Igneous Province. Each of the diagrams has a SiO₂ differentiation index that is compared to each of the major element oxides, both of which are in weight percent oxide.

Fig. 4.8. Harker variation diagrams for mafic to ultramafic rocks (red circles), monzodiorites (blue squares), and nepheline monzonite (green triangles) from the Seiland Igneous Province. The diagrams have a SiO_2 differentiation index that is compared to each of the trace elements. SiO_2 is in weight percent oxide while the trace elements are displayed in parts per million.

Magnesium numbers were calculated using moles of cations: $\text{Mg\#} = 100 \cdot (\text{Mg} / (\text{Mg} + \text{Fe}))$. A plot of $\text{Mg\#}$ versus the whole-rock major element and trace

element abundances reflects mineralogical based correlations with the mafic and ultramafic samples having a higher Mg# and the monzodiorites and nepheline monzonites having lower magnesium numbers (Fig. 4.9 and 4.10). There is a general correlation between decreasing Mg# and increasing abundance of incompatible elements such as Sr, Ba, Zr, and Zn (Fig. 4.10).

Chondrite normalized REE plots for the Seiland rocks show that they are LREE enriched relative to HREEs (Fig. 4.11). The patterns for the mafic to ultramafic rocks have negative slopes, whereas the monzodiorites have negative LREE-MREE slopes and relatively flat HREE patterns. The nepheline monzonites have negative LREE slopes and a slightly positive HREE slope. All samples have positive Eu anomalies that increase in magnitude from ultramafic to mafic samples through the nepheline monzonite sample.

Seiland samples display positively sloping large ion lithophile element (LILE) patterns and are notably enriched in Rb and Ba relative to N-MORB (Fig. 4.12). The nepheline monzonite has distinctive negative anomalies in Sr and Ba. Some high-field strength elements (HFSEs) (Th, Ta, Nb) are enriched compared to N-MORB, whereas others (Zr to Yb) have normalized values closer to unity or less. The N-MORB normalized patterns have generally negative slopes and negative anomalies of different magnitudes. The nepheline monzonite displays a negative anomaly for Ba and Ti (Fig. D). Titanium is also depleted in the monzodiorites (Fig. C). Negative anomalies in phosphorous are observed in all samples. The mafic and ultramafic rocks show a relative depletion in Zr and Ta, and a small positive anomaly in Ti compared to N-MORB.

Figure 4.9. Major element variation diagrams for mafic to ultramafic rocks (red circles), monzodiorites (blue squares), and nepheline monzonite (green triangles) from the Seiland Igneous Province. Each diagram has an Mg # differentiation index that is compared to each of the major element oxides. Magnesium numbers were calculated using moles of cations ($Mg\# = (Mg/(Mg+Fe))$).

Figure 4.10. Trace element variation diagrams for mafic to ultramafic rocks (red circles), monzodiorites (blue squares), and nepheline monzonite (green triangles) from the Seiland Igneous Province. Each diagram has an Mg # differentiation index that is compared to trace elements. Magnesium numbers were calculated using moles of cations ($Mg\# = (Mg/Mg+Fe)$).

Fig. 4.11. Whole-rock chondrite-normalized REE plots for mafic to ultramafic rocks (red circles), monzodiorites (blue squares), and nepheline monzonite (green triangles) from the Seiland Igneous Province. (a) All rock types (b) Mafic/ultramafic rocks (c) Monzodiorites (d) Nepheline Monzonite.

Fig. 4.12. Whole-Rock N-MORB normalized spider plots for selected minor and trace elements in mafic to ultramafic rocks (red circles), monzodiorites (blue squares), and nepheline monzonite (green triangles) from the Seiland Igneous Province. (a) All rock types (b) Mafic/ultramafic rocks (c) Monzodiorites (d) Nepheline Monzonite.

Figure 4.13 is a tectonic discrimination diagram (Pearce and Gale, 1977) that highlights the distinctive enrichment in Ti and Zr (but not Y) that within-plate basalts have relative to other basalts. Pearce and Gale (1977) assign the name plate margin basalts to magmas that do not originate in a within-plate setting, including basalts from early back-arc basins, evolved back-arc basins, island arcs, and continental margins.

The mafic to ultramafic Seiland rocks plot mostly within or slightly above the field for within-plate basalts (Figure 4.14). These samples span the boundary between transitional and alkaline. The monzodiorite plots outside of any of the fields, with high Nb/Y and low Ti/Y ratios. Two data points (monzodiorite, nepheline monzonite) plot outside the diagram, which is to be expected since the diagram is intended for mafic rocks. The monzodiorites and nepheline monzonite samples are plotted for comparison.

On a plot of Zr versus Zr/Y, most of the mafic samples from the Seiland Igneous Province plot in the field for within-plate basalts (Figure 4.15). The samples that do not plot within this field have similar Zr/Y values with lower Zr. Since the diagram is meant for basalts the other SIP samples (monzodiorites, nepheline monzonite) are not plotted.

Fig. 4.13. Tectonic discrimination diagram from (Pearce and Gale, 1977) that highlights the distinctive enrichment in Ti and Zr (but not Y) that within-plate basalts have relative to other basalts. Pearce and Gale assign the name plate margin basalts to magmas that do not originate in a within-plate setting, including basalts from early back-arc basins, evolved back-arc basins, island arcs, and continental margins. Mafic to ultramafic rocks plot as red circles.

Fig. 4.14. Ti/Y-Nb/Y discrimination diagram showing fields of within-plate basalts, MORB, and volcanic-arc basalts. The within-plate basalts are further divided into tholeiitic (Thol), transitional (Trans), and alkaline (Alk) basalt types (after Pearce, 1982). Seiland mafic to ultramafic rocks are plotted as red circles. One monzodiorite is represented by a blue square.

Fig. 4.15. Tectonic discrimination diagram based on variations in Zr/Y and Zr. Volcanic-arc basalts are represented by field A, MORB by field B, and within-plate basalts by field C. Fields that contain mixed settings are D (MORB and volcanic-arc basalts) and E (MORB and within-plate basalts). All boundaries are taken from (Pearce and Norry, 1979).

The Seiland rocks do not plot within the MORB, volcanic-arc basalt (VAB), or within-plate basalt (WPB) fields on the diagram of $K_2O/Yb \cdot 10^{-4}$ versus Ta/Yb (Fig. 4.16). The samples define a trend parallel with an enrichment trend in the within-plate basalts but have lower K_2O/Yb ratios. Mafic to ultramafic samples are the most tholeiitic and span the boundary between tholeiitic and transitional zone. The samples define a trend from tholeiitic to alkaline consistent with enrichment in K_2O and Ta relative to Yb and increasing alkalinity as defined by SiO_2 vs $(Na_2O + K_2O)$. Though this degree of

variance is uncommon for a suite of rocks, it has been seen in ocean island basalts (Bardintzeff et al., 1994) and back-arc basins (Pearce and Stern, 2013).

The mafic to ultramafic Seiland rocks plot in the within-plate basalt field on a diagram of Ce and Ta normalized to Yb (Fig. 4.17). These samples span both the transitional and alkaline envelopes and one of the rocks borders the tholeiitic boundary. Pearce used the diagram for mafic samples only, which may explain why the more felsic samples plot outside the WPB field. These monzodiorite and nepheline monzonite samples are included in order to examine alkalinity of the rocks from a trace element perspective. Increasing alkalinity with increasing silica content is displayed by both major element and trace element perspectives.

The mafic to ultramafic Seiland rocks plot in the overlapping areas of the within-plate basalt and MORB fields on a diagram of Th and Ta normalized to Yb (Fig. 4.18). These samples span both the transitional and alkaline fields. Pearce (1982) used the diagram for mafic samples only, which may explain why the nepheline monzonite plots outside the defined fields. The monzodiorite and nepheline monzonite samples are included to demonstrate the alkalinity of the rocks from a trace element perspective; the plot suggests that all samples display increasing Th/Yb and Ta/Yb ratios with increasing SiO₂ abundance. This signature is caused by the increase of Ta and Th with increasing silica content within the suite.

Fig. 4.16. Tectonic discrimination diagram based on variations in K and Ta using Yb as a normalization factor (after Pearce 1982). Mafic to ultramafic rocks are represented by red circles, monzodiorites by blue squares, and the nepheline monzonite by a green triangle. Fields for MORB, within plate basalts (WPB), and volcanic-arc basalts (VAB) are shown. Tholeiitic (Thol), calc-alkaline (CA), and shoshonitic (Sho) subdivisions are shown within the volcanic-arc basalt field. Within-plate basalts and MORB are subdivided into alkaline (Alk), transitional (Trans), and tholeiitic (Thol) varieties. The intersection of the solid orange arrows represents primordial mantle composition estimated by Wood (1979) and the arrows themselves indicate the direction of mantle depletion (D), mantle enrichment (E), and enrichment caused by a fluid phase subduction component (F). All boundaries are taken from (Pearce 1982).

Fig. 4.17. Tectonic discrimination diagram based on variations in Ce and Ta using Yb as a normalization factor (after Pearce 1982). Mafic to ultramafic rocks are represented by red circles, monzodiorites by blue squares, and the nepheline monzonite by a green triangle. Fields for MORB, within plate basalts (WPB), and volcanic-arc basalts (VAB) are shown. Tholeiitic (Thol), calc-alkaline (CA), and shoshonitic (Sho) subdivisions are shown within the volcanic-arc basalt field. Within-plate basalts and MORB are subdivided into alkaline (Alk), transitional (Trans), and tholeiitic (Thol) varieties.

Fig. 4.18. Tectonic discrimination diagram based on variations in Th and Ta using Yb as a normalization factor (after Pearce 1982). Mafic to ultramafic rocks are represented by red circles, monzodiorites by blue squares, and the nepheline monzonite by a green triangle. Fields for MORB, within plate basalts (WPB), and volcanic-arc basalts (VAB) are shown. Tholeiitic (Thol), calc-alkaline (CA), and shoshonitic (Sho) subdivisions are shown within the volcanic-arc basalt field. Within-plate basalts and MORB are subdivided into alkaline (Alk), transitional (Trans), and tholeiitic (Thol) varieties.

Trace Element Abundances in Minerals

Chondrite normalized rare earth element patterns for amphiboles from the Seiland samples are illustrated in Figure 4.19. The amphiboles in mafic to ultramafic samples are LREE enriched relative to HREEs. The degree of LREE enrichment in amphiboles from the mafic to ultramafic samples varies but is generally 10 to 100 times chondritic. The LREE patterns have flat to slightly positive slopes, with negatively sloped HREE patterns.

Amphiboles from the monzodiorite have a greater enrichment in all of the REEs relative to amphiboles from mafic to ultramafic samples. The REE pattern for the monzodiorite amphiboles are typically flat, albeit with slight positive slopes for the LREEs in samples 241, 243, and 245. Small europium anomalies are present in samples 240, 241, and 243. Sample 241 displays both positive and negative anomalies whereas the other two samples display positive anomalies.

Figure 4.19. Chondrite normalized REE plots for Seiland amphiboles. Amphiboles are separated by rock sample, which is denoted in a corner of each diagram. All samples are mafic to ultramafic with the exception of RJR 245, which is classified as a monzodiorite.

Because there are groups of elements that are known to behave similarly (i.e. LILEs, HFSEs, etc.) representative elements are chosen to illustrate how these groups will behave rather than plotting a multitude of individual elements. Trace elements (Zr, Nb, Sr, Ba, Sc, and V versus Ti) in Figure 4.20 were chosen to represent different element groups, for example, HFSEs are designated by Zr and Nb (Fig. 4.20 a and b). Large ion lithophile elements (LILEs) appear as Sr and Ba (Fig. 4.20 c and d), and the transition metals as Sc and V (Fig. 4.20 e and f). Elements from each group were selected based on their higher measured abundance, which correlated with higher precision, so as to increase the robustness of the data. Multiple analyses from sample 239 contain outlier enrichments in Zr, which can be seen in Fig. 4.20a. Zirconium increases with increasing Ti in all samples until 10,000 ppm Ti is reached. At this point Zr levels reach stability and remain unchanged for the remainder of crystallization. Sample 239 has three outlier points that have a much higher values of Zr than do other spot analyses for the sample. Niobium is similar in that it increases with increasing Ti, however, Nb abundances continue to increase for the duration of crystallization. Amphiboles from sample 245 are significantly more enriched in Nb than in the other samples (Fig. 4.20b). Because Nb abundances in amphiboles from other samples are masked by the large enrichment in amphiboles from sample 245, an additional diagram is provided for a closer look at Nb versus Ti (Fig. 4.21). The amphiboles from this sample are characterized as hastingsite and ferro-tschermakite, which explains the abnormal Nb behavior. Large ion lithophile elements behave similarly in all samples. Strontium increases in all samples with increasing Ti until ~10,000 ppm Ti. Samples 238

and 240 display distinctive trends at higher Sr abundances compared to the other samples. Barium also increases with increasing Ti, but individual sample trends are not as distinct as they are in other LILE plot (Sr versus Ti). The abundance of transition metals (Sc and V) increase with increasing Ti before becoming constant at ~10,000 ppm Ti. Amphiboles from samples 239, 241, and 243 steadily increase in Sc with increasing Ti like those in the other samples, however, these amphiboles do not have analyses for Ti abundances of 10,000 ppm or above, therefore, the stabilization of Sc is not observed here. Vanadium also increases with increasing Ti abundances. Vanadium abundances in samples 238 and 240 stop increasing around 10,000 ppm Ti. Samples 241 and 243 have low abundances of all elements discussed except for the transition metals.

Figure 4.20 (a-f). Trace element variation in amphibole. Symbols represent spot analyses. Each color represents an individual sample (RJR 238= blue, RJR 239= purple, RJR 240= pink, RJR 241= orange, RJR 242= yellow, RJR 243= green, RJR 245= red). All samples are mafic to ultramafic (circles) with the exception of RJR 245, for which spot analyses are denoted by squares. Each plot uses a Ti content as a differentiation index.

Figure 4.21. Trace element variation in amphibole from all samples (a), and all samples except 245 (b). . Symbols represent spot analyses. Each color represents an individual sample (RJR 238= blue, RJR 239= purple, RJR 240= pink, RJR 241= orange, RJR 242= yellow, RJR 243= green, RJR 245= red). All samples are mafic to ultramafic (circles) with the exception of RJR 245, for which spot analyses are denoted by squares.

CHAPTER V

DISCUSSION

Crystal Accumulation

Associated plutonic and volcanic rock suites commonly have comparable bulk-rock compositional trends (Coleman et al., 2012), however, evidence of divergence in compositional trends due to crystal accumulation is commonly reported (Barnes et al., 2016a; Naslund and McBirney, 1996; Wagner and Brown, 1968). Fractional crystallization of mafic magmas leads to the production of intermediate to felsic magmas, leaving behind an accumulation of crystals (Keller et al., 2015). Once the melt is separated from the residual cumulate it may undergo fractional crystallization, magma mixing, assimilation, etc., which may potentially establish contrasting trace element trends to develop between the magmatic products. Because the mafic residue crystallized first, and has a lower silica content than the intermediate to felsic magmas (Barnes et al., 2016a) it is expected to be richer in elements that are compatible with early crystallizing phases such as calcic plagioclase, pyroxenes, and amphiboles. Bulk-rock compositional features such as high concentrations of MgO, Al₂O₃, and Cr may indicate accumulation of ferromagnesian silicates, plagioclase, and augite or chromite, respectively (Barnes et al., 2016a; Keller et al., 2015). A cumulate rock is also predicted to have euhedral interlocking crystals, brought on by the stacking of crystals during accumulation (Wagner

et al., 1960). Intercumulate space between the cumulate minerals will be filled with anhedral grains of later crystallizing minerals.

Silica contents of the SIP mafic to ultramafic samples is lower than the monzodiorites and nepheline monzonite which could be caused by accumulation if there was a single parental melt, however, the mantle source (Roberts et al., 2010) alone could also cause the low silica values for the mafic samples. The mafic and ultramafic samples are dominated by amphiboles, therefore, high magnesium numbers paired with elevated abundances of Cr, Al_2O_3 , and Ni would indicate the samples are a product of crystal accumulation. Figure 5.1 highlights elevated abundances of Cr and Ni for one of the samples, indicated by the black arrow on the diagrams. This sample (RJR 239) contains 955 ppm Cr and 375.8 ppm Ni, which are elevated relative to what is expected for alkali basalts (Cr <600, Ni <300). These elevated abundances are likely to be generated as a result of crystal accumulation. However, crystal accumulation is also expected to cause elevated levels of Al_2O_3 , which is not seen (Al_2O_3 = 9.46 wt. %). Two additional points that represent the same sample (RJR 242) are slightly elevated in Cr (622, 613.5) but display Ni and Al_2O_3 values that are anticipated for alkali basalts (Ni=201.8, 201.2; Al_2O_3 = 12.6, 12.6). The Eu anomalies present in the monzodiorites and nepheline monzonite could be indicative of late accumulation of plagioclase, which is supported by the low abundances of other MREEs.

Two samples are at risk to have been affected by crystal accumulation of amphibole based on Mg#, Cr, Ni, and Al_2O_3 contents. However, neither sample has all of

the geochemical indicators expected of a cumulate rock. Sample 239 is the most likely to have undergone accumulation because it has the highest Mg#, Cr, and Ni contents, yet it also contains the lowest abundance of Al₂O₃, which is opposite of what is expected for a cumulate rock. These data insufficiencies do not allow confident characterization of these samples to be cumulates, and therefore, they are included in the geochemical study and interpretation of primary melt compositions.

Figure 5.1. Variation diagrams for mafic to ultramafic rocks (red circles), monzodiorites (blue squares), and nepheline monzonite (green triangles) from the Seiland Igneous Province. Each diagram has an Mg # differentiation index that is compared to each of the major element oxides. Magnesium numbers were calculated using moles of cations ($Mg\# = (Mg/Mg+Fe)$).

Tectonic Discrimination

Because of the link between alkaline rocks and extensional tectonic environments, exploration of whether the Seiland Igneous Province rocks were emplaced into a back-arc basin or a continental rift is required. Distinguishing between these extensional environments using geochemical methods is challenging because they are often geochemically similar. Notable characteristics of back-arc basins include the enrichment of large ion lithophile elements relative to MORB (LILEs; (Gill, 1976), which has been interpreted by (Stolper and Newman, 1994) to be a result of fluid movement. However, it has also been argued that rift-related rocks may have similar trace element geochemical signatures if crustal material is incorporated (Furman, 2007). On the other hand, it has been proposed that differentiating between the two environments may be possible using high field strength element abundances/ratios (HFSEs). A decrease in HFSEs paired with an increase in LILEs relative to MORB is indicative of a back-arc basin (Gill, 1976), whereas in a continental rift the LILE enrichment may be present if crustal material has been incorporated (Furman, 2007). The only difference between these trends is that the continental rift setting would not produce the LILE enrichment paired with HFSE depletion that the back-arc basin may produce. The trends for back-arc basins are both connected to water content, LILE enrichment developing by element transport in the aqueous component and the HFSE depletion being generated by increased melting due to

the addition of a fluid component (Stolper and Newman, 1994). Figure 5.2 graphically represents these relationships by illustrating the geochemical differences between continental rifts and back-arc basin environments. The most prominent difference in the patterns is the depletion of high-field strength elements, including Ta and Nb, in mafic rocks from back-arc basins relative to those from continental rifts. Figure 5.3 is a combination of each spider diagrams for continental rifts, back-arc basins, and the Seiland samples from this study. The Seiland rocks lack the characteristic HFSE depletion of back-arc basins, and are enriched 5-100x MORB in Ta and Nb, further supporting the continental rift setting argument.

Figure 5.2. (a). N-MORB normalized spider diagrams for mafic rocks from continental rift settings (shades of gray). (b) N-MORB normalized spider diagrams for mafic rocks from back-arc basins (shades of yellow). MORB values were taken from (Sun and McDonough, 1989). The data were downloaded from the PetDB Database (www.earthchem.org/petdb) on 17 August, 2017, using the following parameters: Sample type= Igneous;Mafic and tectonic setting= continental rift and back-arc basin (Lehnert et al., 2000). Continental rift data originally from (Gottfried et al., 1983; Hughes et al., 2015). Back-arc basin data originally from (Ewart and Griffin, 1994; Fretzdorff et al., 2002; Harrison et al., 2003; Ishizuka et al., 2003; Jenner et al., 2010; Leat et al., 2000; Pearce et al., 1994).

Figure 5.3. N-MORB normalized spider diagram for the Seiland Igneous Province samples. Mafic to ultramafic samples are represented by red circles, monzodiorites by blue squares, and the nepheline monzonite by green triangles. Windows representing the data from Figure 5.2 is underlain for comparison. Gray windows represent rift settings and yellow represents back-arc basin settings.

Chondrite normalized rare earth element patterns for samples from continental rifts and back-arc basins are also quite distinctive (Fig. 5.4), with rift magmas having negatively sloped patterns and more enrichment in LREEs than back-arc basins. Back-arc basin patterns have slightly positive sloped LREE patterns that range from 3 to 25 times chondrites whereas the continental rifts span a range of 20 to 170x chondrites. A rare earth element diagram for the Seiland samples is overlain on the rift and back-arc plot in Figure 5.5. The Seiland samples share the overall negative slope and dominant LREE enrichment that the continental rift plot displays.

Figure 5.4. Bulk-rock chondrite-normalized REE plots for mafic rocks from continental rift settings (gray diamonds) and back-arc basin settings (yellow squares). Chondrite values taken from (Sun and McDonough, 1989). The data were downloaded from the PetDB Database (www.earthchem.org/petdb) on 16 August, 2017, using the following parameters: Sample type= Igneous;Mafic and tectonic setting= continental rift and back-arc basin (Lehnert et al., 2000). Continental rift data originally from (Dostal and Dupuy, 1984; Gottfried et al., 1983; Hughes et al., 2015; Merle et al., 2011). Back-arc basin data originally from (Ewart and Griffin, 1994; Tamura et al., 2007).

Figure 5.5 overlays the Seiland data on the data from Figure 5.4. Chondrite values are taken from (Sun and McDonough, 1989). Mafic to ultramafic samples are represented by red circles, monzodiorites by blue squares, and the nepheline monzonite by green triangles.

Major element abundances and trends in mafic rocks from rifts and back-arcs are not particularly distinctive. Harker diagrams for rocks from each setting (Fig. 5.6) display large overlaps that restrict the application of major elements for tectonic discrimination. However, despite the general overlap between the rift and back-arc data, the Seiland rocks trend towards continental rifts, especially in terms of MnO, MgO, and CaO.

Pearce (1982) developed a method of differentiating between basalts from oceanic settings (volcanic-arcs and mid-ocean ridges) and intraplate basalts, which were called

within-plate basalts (Pearce, 1982). Continental rift basalts should plot in the within-plate basalt field (WPBs), but because back-arc basin magmas have so much variance they may plot in compositional space spanning from the volcanic-arc basalt to the MORB fields (Pearce, 1982; Pearce and Stern, 2013). The Seiland rocks plot outside of any field on Fig. 4.16, lying just below the MORB and WPB fields at a lower K_2O/Yb value. This behavior is interpreted to be a result of potassium mobility during fluid alteration, which is consistent with documented metasomatism of the surrounding host rock to the studied dikes, which was attributed to the alkaline intrusions of the SIP (Robins and Tysseland, 1983; Sturt and Ramsay, 1965). Tantalum values are not affected because Ta is insoluble in hydrothermal fluids. Though this diagram is not conclusive, it does highlight the high Ta abundances in these rocks from the Seiland Igneous Province, compared to examples of back-arc basin basalts (Fig. 5.2). Because the K abundances in the rocks may have been altered by metasomatic processes, figures 4.17 and 4.18, which were originally plotted using K, are re-plotted using Ce and Th. Cerium and Th are used because they are commonly found within the same minerals, such as amphiboles and biotite, but are considered less mobile and therefore their abundances are considered less susceptible than K to alteration (Pearce, 1982). A plot of Th/Yb versus Ta/Yb shows the Seiland rocks plot in the overlap for the within-plate basalts and MORB fields, which could indicate a continental rift setting or back-arc basin setting (Fig. 4.18). Figure 4.17 provides less uncertainty because the fields do not overlap as much and the Seiland basalts plot in the within-plate basalt field in an area that has no overlap. This diagram

also points towards a rift setting interpretation, however, it is noted that some back-arc basin basalts plot in both the VAB and WPB sections of these diagrams, due in part to mantle heterogeneities and varying subduction component influences (Pearce, 1982). Mantle heterogeneities potentially result from variable temperature, fertility and/or provenance of the mantle that feeds the back-arc basin (Pearce, 1982). Shifts in subduction components depend on the composition of the material being subducted, as well as how it was transported into the system (Pearce, 1982). Apart from the variability of these feeder components, interaction between them, such as timing relative to melting and degree of mixing, can also result in inconsistencies (Pearce, 1982).

Figure 5.6. Harker variation diagrams for mafic to ultramafic Seiland rocks (green triangles), mafic rocks from back-arc basins (red squares), and mafic rocks from continental rifts (blue diamonds). The rift and back-arc data were downloaded from the PetDB Database (www.earthchem.org/petdb) on 18 August, 2017, using the following parameters: Sample type= Igneous;Mafic and tectonic setting=

continental rift and back-arc basin (Lehnert et al., 2000). Continental rift data originally from (Cebri et al., 2003; Dostal and Dupuy, 1984; Gottfried et al., 1983; Husch, 1992; Husch et al., 1984; Merle et al., 2011; Shirley, 1987; Warner et al., 1985). Back-arc basin data originally from (Davies and Macdonald, 1987; Ewart and Griffin, 1994; Frenzel et al., 1990; Hawkins, 1976; Hawkins and Melchior, 1985; Pearce et al., 1994; Price et al., 2016; Stern et al., 1989; Tamura et al., 2011; Tamura et al., 2007; Vallier et al., 1991).

Alkaline Rocks in Wilson Cycles

Alkaline rocks occur in continental rift settings around the world, such as the East Africa Rift, Rio Grande Rift (USA), Baikal Rift (Russia), Oslo Graben (Norway), Narmada-Son Rift (India), and Gardar Province (Greenland) (Sen, 2014). Alkaline rocks have also been documented in regions that preserve contractional deformation, leading to a distinction between alkaline rocks and carbonatites (ARCs) and deformed alkaline rocks and carbonatites (DARCs) (Burke and Khan, 2006), both of which can be assigned to a Wilson Cycle stage. ARCs form in the early stages of ocean basin opening by continental rifting (Fig. 5.7) (Burke and Khan, 2006). These ARCs are subsequently deformed when the rifted continental margins collide with an island arc or continent during closure the ocean basin at the end of a Wilson Cycle (Burke and Khan, 2006), and therefore document the full Wilson Cycle. A new Wilson Cycle would be initiated if rifting at the suture zone is renewed, in which case new ARCs may form by melting the previously emplaced DARCs during decompression (Fig. 5.7) (Burke and Khan, 2006). Burke defined ARCs as nepheline syenites and their volcanic equivalents, tephrites, phonolites, and carbonatites that are erupted into rift environments. DARCs are

geochemically and petrographically identical and only differ from ARCs in their deformation (Burke and Khan, 2006). Alkaline rocks and carbonatites form intrusions that are usually round, while DARC intrusions are often lensoidal as a result of deformation and may be granulitic or gneissic (Burke and Khan, 2006).

Mapping of the Seiland Igneous Province (Roberts et al., 2006; Sturt and Ramsay, 1965) documented km-scale lenses of alkaline rocks on Sørøy (Fig. 5.8). Some intrusions display deformational fabrics whereas others do not, which is interpreted to be a result of the larger bodies being more readily deformed because of their ability to hold ambient temperatures longer than their smaller counterparts (Roberts et al., 2006). The presence of foliation and the elongate shape of the intrusions (Fig. 5.8) is used to argue that these rocks represent DARCs. While the Iepetus was in existence these ARCs remained on the margin of Laurentia, until the SIP and the Kalak sediments were transferred onto the margin of Baltica to their present day position during the Caledonian Orogeny. This orogenic event closed Iepetus, ending the Wilson Cycle and deforming the ARCs into the DARCs of the SIP (Burke et al., 2007). Paleogeography of the area (Fig. 5.9) shows initiation of Rodinia breakup at 600 Ma. The Seiland Igneous Province was emplaced as ARCs into the Kalak sediments as a result of this rift, which were located on the margin of Laurentia at that time. Additional rocks related to this rifting event are found in present-day Virginia and are known as the Catoctin Volcanics (Badger and Sinha, 1988; Rankin, 1975).)

Figure 5.7. A: Cartoon illustrating how alkaline rocks and carbonatites (ARCS) are erupted into continental rifts. **B:** Cartoon illustrating placement of those ARCS on rifted continental margins when an ocean basin develops in the rift center. **C:** Cartoon illustrating a continental collision and suturing during ocean closure that deforms the ARCS, creating deformed alkaline rocks and carbonatites (DARCS). **D:** Cartoon illustrating DARC placement during tectonic inactivity. **E:** Cartoon illustrating renewed rifting at the suture site that causes decompression melting (Burke et al., 2007) of the previously emplaced DARCS that will cause formation of new ARCS. Figure taken from (Burke and Khan, 2006).

Figure 5.8. Geologic map of the island of Sørøy, northern Norway, showing the locations of igneous intrusions mentioned in the text (Roberts et al., 2006).

Figure 5.9. Paleogeography of the area from 600 to 400 Ma. Colorado Plateau Geosystems ©.

Temperature and Pressure

Previous estimates for pressure of emplacement of the Seiland Igneous rocks are around 6-8 kbar (Reginiussen, 1996; Roberts et al., 2006). This estimate was tested in this study using the Al-in hornblende barometer (Schmidt, 1992) on the Seiland rocks that

contained the required mineral assemblage (hornblende + biotite + plagioclase + orthoclase + quartz + sphene + Fe-Ti oxides). This barometer was created using calc-alkaline systems and although the samples tested here have a tholeiitic trend they are appropriate for use given the presence of the required mineral assemblage. LA-ICPMS data from amphibole rims in samples 238 and 240 was used to calculate an estimated pressure range from $6.89\text{-}7.95 \pm 0.6$ kbar. These pressures indicate a depth of 20 to 30 km, which would represent a lithospheric crystallization depth. Temperature estimates using amphibole compositions range from 710 to 960 °C for the mafic to ultramafic samples, and 650-665°C for the nepheline monzonite (Putirka, 2016). The pressure and temperature calculations are within the realm of possibility for the proposed continental rift setting.

Table 5.1. Calculated pressures for the SIP rocks.

Sample-Grain-Spot	Al (apfu)	Pressure (kbar)
RJR238-AM1-F	2.08	6.8908
RJR238-AM3-A	2.152	7.23352
RJR238-AM3-B	2.121	7.08596
RJR238-AM6-A	2.079	6.88604
RJR240-AM1-A	2.243	7.66668
RJR240-AM2-A	2.175	7.343
RJR240-AM3-B	2.193	7.42868
RJR240-AM5-A	2.302	7.94752
RJR240-AM5-G	2.288	7.88088
RJR240-AM6-B	2.221	7.56196
RJR240-AM6-C	2.222	7.56672
RJR240-AM7-A	2.237	7.63812
RJR242-AM1A	2.108	7.02408
RJR242-AM2-A	2.169	7.31444
RJR242-AM4-B	2.136	7.15736

CHAPTER VI

CONCLUSIONS

Data for the mafic samples of this study does indicate that accumulation may have influenced at least two of the samples, however, these samples also contain geochemical indicators that suggest accumulation has not affected them. Confident conclusions that accumulation had occurred were prevented by these disagreements. As such, the results of the geochemical study are proposed to represent primary melt compositions of mantle-derived magmas.

Alkaline rocks are known to be associated with extensional environments. The Seiland samples lack HFSE depletion, which when paired with their enrichment in LILEs relative to MORB, indicates that the rocks are more likely to have been emplaced into a continental rift environment, rather than a back-arc basin. Enrichment of light REEs relative to heavy REEs, as well as trends in major element variation agree with this conclusion.

Alkaline rocks from continental rifts may be described in terms of the temporal placement within a Wilson Cycle. The Seiland Igneous rocks were emplaced as ARC's onto the margin of Baltica during rifting along the Lapland Kola Suture, which eventually led to what would become the Iapetus Ocean. The ARC's remained on the margin of Baltica until Iapetus closure. The Caledonian Orogeny terminated the Iapetus and

deformed the Seiland ARCs into the present day DARCs. These conclusions are consistent with those of (Burke et al., 2007).

REFERENCES

- Badger, R.L., and Sinha, A.K. (1988) Age and Sr isotopic signature of the Catoctin volcanic province: Implications for subcrustal mantle evolution. *Geology*, 16(8), 692-695.
- Bardintzeff, M.-J., Leyrit, H., Guillou, H., Guille, G., Bonin, B., Giret, A., and Brousse, R. (1994) Transition between tholeiitic and alkali basalts: Petrographical and geochemical evidence from Fangataufa, Pacific Ocean, and Kerguelen, Indian Ocean. *Geochemical Journal*, 28 (No. 6), 489-515.
- Barnes, C.G., Coint, N., and Yoshinobu, A. (2016a) Crystal accumulation in a tilted arc batholith. *American Mineralogist*, 101(8), 1719-1734.
- Barnes, C.G., Ernst, W.G., Berry, R., and Tsujimori, T. (2016b) Petrology and Geochemistry of an Upper Crustal Pluton: a view into Crustal-scale Magmatism during Arc to Retro-arc Transition. *Journal of Petrology*, 57(7), 1361-1388.
- Barnes, C.G., Memeti, V., and Coint, N. (2016c) Deciphering magmatic processes in calc-alkaline plutons using trace element zoning in hornblende. *American Mineralogist*, 101(2), 328-342.
- Bennett, M.C., Emblin, S.R., Robins, B., and Yeo, W.J.A. (1986) High-temperature ultramafic complexes in the North Norwegian Caledonides: I - Regional setting and field relationships Norges Geologiske Undersøkelse, Bulletin 405, 1-40.
- Burke, K., and Khan, S. (2006) Geoinformatic approach to global nepheline syenite and carbonatite distribution: Testing a Wilson cycle model. *Geosphere*, 2(1), 53-60.
- Burke, K., Roberts, D., and Ashwal, L.D. (2007) Alkaline rocks and carbonatites of northwestern Russia and northern Norway: Linked Wilson cycle records extending over two billion years. *Tectonics*, 26(4).
- Cadow, R. (1993) Sm-Nd and Rb-Sr ages of hornblende clinopyroxenite and metagabbro from the Lillebukt Alkaline Complex, Seiland Igneous Province. *Norsk Geologisk Tidsskrift*, 73, 243-249.
- Cebri, J.M., Lpez-Ruiz, J., Doblas, M., Martins, L.T., and Munha, J. (2003) Geochemistry of the Early Jurassic Messejana–Plasencia dyke (Portugal–Spain);

- Implications on the Origin of the Central Atlantic Magmatic Province. *Journal of Petrology*, 44(3), 547-568.
- Coint, N., Barnes, C.G., Yoshinobu, A.S., Barnes, M.A., and Buck, S. (2013) Use of trace element abundances in augite and hornblende to determine the size, connectivity, timing, and evolution of magma batches in a tilted batholith. *Geosphere*, 9(6), 1747-1765.
- Coleman, D.S., Bartley, J.M., Glazner, A.F., and Pardue, M.J. (2012) Is chemical zonation in plutonic rocks driven by changes in source magma composition or shallow-crustal differentiation? *Geosphere*, 8(6), 1568-1587.
- Collins, W.J. (2003) Slab pull, mantle convection, and Pangaeon assembly and dispersal. *Earth and Planetary Science Letters*, 205(3), 225-237.
- Corfu, F., Andersen, T.B., and Gasser, D. (2014) The Scandinavian Caledonides: main features, conceptual advances and critical questions. Geological Society, London, Special Publications, 390(1), 9-43.
- Corfu, F., Roberts, R.J., Torsvik, T.H., Ashwal, L.D., and Ramsay, D.M. (2007) Peri-Gondwanan elements in the Caledonian Nappes of Finnmark, Northern Norway: Implications for the paleogeographic framework of the Scandinavian Caledonides. *American Journal of Science*, 307(2), 434-458.
- Dalziel, I.W.D. (1997) OVERVIEW: Neoproterozoic-Paleozoic geography and tectonics: Review, hypothesis, environmental speculation. *Geological Society of America Bulletin*, 109(1), 16-42.
- Davies, G.R., and Macdonald, R. (1987) Crustal Influences in the Petrogenesis of the Naivasha Basalt-Comendite Complex: Combined Trace Element and Sr-Nd-Pb Isotope Constraints. *Journal of Petrology*, 28(6), 1009-1031.
- Deering, C.D., and Bachmann, O. (2010) Trace element indicators of crystal accumulation in silicic igneous rocks. *Earth and Planetary Science Letters*, 297(1), 324-331.
- Dostal, J., and Dupuy, C. (1984) Geochemistry of the North Mountain basalts (Nova Scotia, Canada). *Chemical Geology*, 45(3), 245-261.
- Ewart, A., and Griffin, B.J. (1994) Proton-microprobe trace element study of selected leg 135 core samples. *Proc ODP, SCI results*, 135, 533-542.

- Frenzel, G., MÜhe, R.K., and Soffers, P. (1990) Petrology of the volcanic rocks from the Lau Basin, southwest Pacific Geol. JAHRB, 92, 395-479.
- Fretzdorff, S., Livermore, R.A., Devey, C.W., Leat, P.T., and Stoffers, P. (2002) Petrogenesis of the Back-arc East Scotia Ridge, South Atlantic Ocean. *Journal of Petrology*, 43(8), 1435-1467.
- Furman, T. (2007) Geochemistry of East African Rift basalts: An overview. *Journal of African Earth Sciences*, 48, 147-160.
- Gayer, R.A., Hayes, S.J., and Rice, A.H.N. (1985) The structural development of the Kalak Nappe Complex of Eastern and Central Porsangerhalyøya, Finnmark, Norway. *Norges Geologiske Undersøkelse, Bulletin 400*, 67-87.
- Gill, J.B. (1976) Composition and age of Lau Basin and Ridge volcanic rocks: Implications for evolution of an interarc basin and remnant arc. *Geological Society of America Bulletin*, 87(10), 1384-1395.
- Gottfried, D., Ansell, C.S., and Byerly, G.R. (1983) Geochemistry and tectonic significance of subsurface basalts near Charleston, South Carolina: Clubhouse crossroads test holes #2 and #3. *US Geological Survey Professional Papers*, 1313-A, 1-19.
- Harrison, D., Leat, P.T., Burnard, P.G., Turner, G., Fretzdorff, S., and Millar, I.L. (2003) Resolving mantle components in oceanic lavas from segment E2 of the East Scotia back-arc ridge, South Sandwich Islands. *Geological Society, London, Special Publications*, 219(1), 333-344.
- Hawkins, J.W. (1976) Petrology and geochemistry of basaltic rocks of the Lau Basin. *Earth and Planetary Science Letters*, 28(3), 283-297.
- Hawkins, J.W., and Melchior, J.T. (1985) Petrology of Mariana Trough and Lau Basin basalts. *Journal of Geophysical Research: Solid Earth*, 90(B13), 11431-11468.
- Hoernle, K., Tilton, G., Le Bas, M.J., Duggen, S., and Garbe-Schönmberg, D. (2002) Geochemistry of oceanic carbonatites compared with continental carbonatites: mantle recycling of oceanic crustal carbonate. *Contributions to Mineralogy and Petrology*, 142(5), 520-542.
- Holtedahl, O., and Dons, J.A. (1960) Geologisk kart over Norge. *Norges Geologiske Undersøkelse, Bulletin 208*, 15p.

- Hou, Z., Liu, Y., Tian, S., Yang, Z., and Xie, Y. (2015) Formation of carbonatite-related giant rare-earth-element deposits by the recycling of marine sediments. *Scientific Reports*, 5, 10231.
- Hou, Z., Tian, S., Yuan, Z., Xie, Y., Yin, S., Yi, L., Fei, H., and Yang, Z. (2006) The Himalayan collision zone carbonatites in western Sichuan, SW China: Petrogenesis, mantle source and tectonic implication. *Earth and Planetary Science Letters*, 244(1–2), 234-250.
- Hughes, H.S.R., McDonald, I., and Kerr, A.C. (2015) Platinum-group element signatures in the North Atlantic Igneous Province: Implications for mantle controls on metal budgets during continental breakup. *Lithos*, 233, 89-110.
- Husch, J.M. (1992) Geochemistry and petrogenesis of early Jurassic diabase from the central Newark Basin of New Jersey and Pennsylvania. *Geological Society of America Special Papers*, 268, 169-192.
- Husch, J.M., Sturgis, D.S., and Bambrick, T.C. (1984) Mesozoic diabases from West-Central New Jersey: Major and trace element geochemistry of whole rock samples *Northeastern Geology*, 6, 51-63.
- Ishizuka, O., Taylor, R.N., Milton, J.A., and Nesbitt, R.W. (2003) Fluid–mantle interaction in an intra-oceanic arc: constraints from high-precision Pb isotopes. *Earth and Planetary Science Letters*, 211(3–4), 221-236.
- Jenner, F.E., O'Neill, H.S.T.C., Arculus, R.J., and Mavrogenes, J.A. (2010) The Magnetite Crisis in the Evolution of Arc-related Magmas and the Initial Concentration of Au, Ag and Cu. *Journal of Petrology*, 51(12), 2445-2464.
- Jones, A.P., Genge, M., and Carmody, L. (2013) Carbonate Melts and Carbonatites. *Reviews in Mineralogy and Geochemistry*, 75(1), 289-322.
- Keller, C.B., Schoene, B., Barboni, M., Samperton, K.M., and Husson, J.M. (2015) Volcanic-plutonic parity and the differentiation of the continental crust. *Nature*, 523(7560), 301-307.
- Kovalenko, V.I., Yarmolyuk, V.V., and Bogatkov, O.A. (2010) The contemporary North Pangea supercontinent and the geodynamic causes of its formation. *Geotectonics*, 44(6), 448-461.
- Leat, P.T., Livermore, R.A., Millar, I.L., and Pearce, J.A. (2000) Magma Supply in Back-arc Spreading Centre Segment E2, East Scotia Ridge. *Journal of Petrology*, 41(6), 845-866.

- Lehnert, K., Su, Y., Langmuir, C.H., Sarbas, B., and Nohl, U. (2000) A global geochemical database structure for rocks. *Geochemistry, Geophysics, Geosystems*, 1(5), n/a-n/a.
- Li, Z.X., Bogdanova, S.V., Collins, A.S., Davidson, A., De Waele, B., Ernst, R.E., Fitzsimons, I.C.W., Fuck, R.A., Gladkochub, D.P., Jacobs, J., Karlstrom, K.E., Lu, S., Natapov, L.M., Pease, V., Pisarevsky, S.A., Thrane, K., and Vernikovsky, V. (2008) Assembly, configuration, and break-up history of Rodinia: A synthesis. *Precambrian Research*, 160(1-2), 179-210.
- Meert, J.G., and Torsvik, T.H. (2003) The making and unmaking of a supercontinent: Rodinia revisited. *Tectonophysics*, 375(1), 261-288.
- Merle, R., Marzoli, A., Bertrand, H., Reisberg, L., Verati, C., Zimmermann, C., Chiaradia, M., Bellieni, G., and Ernesto, M. (2011) $^{40}\text{Ar}/^{39}\text{Ar}$ ages and Sr–Nd–Pb–Os geochemistry of CAMP tholeiites from Western Maranhão basin (NE Brazil). *Lithos*, 122(3–4), 137-151.
- Naslund, H.R., and McBirney, A.R. (1996) Mechanisms of Formation of Igneous Layering. *Developments in Petrology*, 15, 1-43.
- Pearce, J.A. (1982) Trace element characteristics of lavas from destructive plate boundaries. In: Thorpe R.S. (ed.), *Andesites*. Wiley, Chichester, 525-548.
- Pearce, J.A., Ernewein, M., Bloomer, S.H., Parson, L.M., Murton, B.J., and Johnson, L.E. (1994) Geochemistry of Lau Basin volcanic rocks: influence of ridge segmentation and arc proximity. Geological Society, London, Special Publications, 81(1), 53-75.
- Pearce, J.A., and Stern, R.J. (2013) Origin of Back-Arc Basin Magmas: Trace Element and Isotope Perspectives. *Back-Arc Spreading Systems: Geological, Biological, Chemical, and Physical Interactions*, p. 63-86. American Geophysical Union.
- Pederson, R.B., Dunning, G.R., and Robins, B. (1989) U - Pb ages of nepheline syenite pegmatites from the Seiland Magmatic Province, N. Norway *The Caledonide Geology of Scandinavia* (ed. R. A. Gayer), 3-8
- Price, A.A., Jackson, M.G., Blichert-Toft, J., Blusztajn, J., Conatser, C.S., Konter, J.G., Koppers, A.A.P., and Kurz, M.D. (2016) Geochemical evidence in the northeast Lau Basin for subduction of the Cook-Austral volcanic chain in the Tonga Trench. *Geochemistry, Geophysics, Geosystems*, 17(5), 1694-1724.

- Putirka, K. (2016) Amphibole thermometers and barometers for igneous systems and some implications for eruption mechanisms of felsic magmas at arc volcanoes. *American Mineralogist*, 101(4), 841-858.
- Putnis, A. (1992) *Introduction to Mineral Sciences*. Press Syndicate of the University of Cambridge, Cambridge.
- Rankin, D.W. (1975) The Continental Margin of Eastern North America in the Southern Appalachians: The Opening and Closing of the Proto-Atlantic Ocean. *American Journal of Science*, 275-A, 298-336.
- Reginiussen, H. (1996) Unpublished Ph.D thesis. University of Trømso.
- Roberts, R.J., Corfu, F., Torsvik, T.H., Ashwal, L.D., and Ramsay, D.M. (2006) Short-lived mafic magmatism at 560–570 Ma in the northern Norwegian Caledonides: U–Pb zircon ages from the Seiland Igneous Province. *Geological Magazine*, 143(6), 887-903.
- Roberts, R.J., Corfu, F., Torsvik, T.H., Hetherington, C.J., and Ashwal, L.D. (2010) Age of alkaline rocks in the Seiland Igneous Province, Northern Norway. *Journal of the Geological Society*, 167(1), 71-81.
- Robins, B. (1996) Field Trip Guidebook: The Seiland Igneous Province, North Norway. *Norges Geologiske Undersøkelse Report 96.127*, 30p.
- Robins, B., and Gardner, P.M. (1975) The magmatic evolution of the Seiland province, and Caledonian plate boundaries in northern Norway. *Earth and Planetary Science Letters*, 26(2), 167-178.
- Robins, B., and Tysseland, M. (1983) The geology, geochemistry and origin of ultrabasic fenites associated with the Pollen Carbonatite (Finnmark, Norway). *Chemical Geology*, 40(1), 65-95.
- Schmidt, M.W. (1992) Amphibole composition in tonalite as a function of pressure: an experimental calibration of the Al-in-hornblende barometer. *Contributions to Mineralogy and Petrology*, 110(2), 304-310.
- Shirley, D.N. (1987) Differentiation and Compaction in the Palisades Sill, New Jersey. *Journal of Petrology*, 28(5), 835-865.
- Stephens, M.B., and Gee, D.G. (1989) Terranes and polyphase accretionary history in the Scandinavian Caledonides. *Geological Society of America Special Papers*, 230, 17-30.

- Stern, R.J., Bloomer, S.H., Lin, P.-N., and Smoot, N.C. (1989) Submarine arc volcanism in the southern Mariana Arc as an ophiolite analogue. *Tectonophysics*, 168(1), 151-170.
- Stolper, E., and Newman, S. (1994) The role of water in the petrogenesis of Mariana trough magmas. *Earth and Planetary Science Letters*, 121(3), 293-325.
- Sturt, B.A., Pringle, I.R., and Ramsay, D.M. (1978) The Finnmarkian phase of the Caledonian Orogeny. *Journal of the Geological Society*, 135(6), 597-610.
- Sturt, B.A., and Ramsay, D.M. (1965) The alkaline complex of the Breivikbotn area, Sørøy, Northern Norway. *Norges Geologiske Undersøkelse, Bulletin* 231, 1-142.
- Sun, S.s., and McDonough, W.F. (1989) Chemical and isotopic systematics of oceanic basalts: implications for mantle composition and processes. *Geological Society, London, Special Publications*, 42(1), 313-345.
- Tamura, Y., Ishizuka, O., Stern, R.J., Shukuno, H., Kawabata, H., Embley, R.W., Hirahara, Y., Chang, Q., Kimura, J.I., Tatsumi, Y., Nunokawa, A., and Bloomer, S.H. (2011) Two Primary Basalt Magma Types from Northwest Rota-1 Volcano, Mariana Arc and its Mantle Diapir or Mantle Wedge Plume. *Journal of Petrology*, 52(6), 1143-1183.
- Tamura, Y., Tani, K., Chang, Q., Shukuno, H., Kawabata, H., Ishizuka, O., and Fiske, R.S. (2007) Wet and Dry Basalt Magma Evolution at Torishima Volcano, Izu–Bonin Arc, Japan: the Possible Role of Phengite in the Downgoing Slab. *Journal of Petrology*, 48(10), 1999-2031.
- Torsvik, T.H., Smethurst, M.A., Meert, J.G., Van der Voo, R., McKerrow, W.S., Brasier, M.D., Sturt, B.A., and Walderhaug, H.J. (1996) Continental break-up and collision in the Neoproterozoic and Palaeozoic – A tale of Baltica and Laurentia. *Earth-Science Reviews*, 40(3), 229-258.
- Vallier, T.L., Jenner, G.A., Frey, F.A., Gill, J.B., Davis, A.S., Volpe, A.M., Hawkins, J.W., Morris, J.D., Cawood, P.A., Morton, J.L., Scholl, D.W., Rautenschlein, M., White, W.M., Williams, R.W., Stevenson, A.J., and White, L.D. (1991) Subalkaline andesite from Valu Fa Ridge, a back-arc spreading center in southern Lau Basin: petrogenesis, comparative chemistry, and tectonic implications. *Chemical Geology*, 91(3), 227-256.
- Wagner, L.R., and Brown, G.M. (1968) *Layered Igneous Rocks*. Oliver and Boyd, Edinburgh.

- Wagner, L.R., Brown, G.M., and Wadsworth, W.J. (1960) Types of igneous cumulates. *Journal of Petrology*(1), 73-85.
- Warner, R.D., Snipes, D.S., Hughes, S.S., Steiner, J.C., Davis, M.W., Manoogian, P.R., and Schmitt, R.A. (1985) Olivine-normative dolerite dikes from western South Carolina: Mineralogy, chemical composition and petrogenesis. *Contributions to Mineralogy and Petrology*, 90(4), 386-400.
- Barnes, C.G., Frost, C.D., Yoshinobu, A.S., McArthur, K., Barnes, M.A., Allen, C.M., Nordgulen, Ø., and Prestvik, T. (2007) Timing of sedimentation, metamorphism, and plutonism in the Helgeland Nappe Complex, north-central Norwegian Caledonides. *Geosphere*, 3(6), 683-703.
- Cadow, R. (1993) Sm-Nd and Rb-Sr ages of hornblende clinopyroxenite and metagabbro from the Lillebukt Alkaline Complex, Seiland Igneous Province. *Norsk Geologisk Tidsskrift*, 73, 243-249.
- Daly, J.S., Aitcheson, S.J., Cliff, R.A., Gayer, R.A., and Rice, A.H.N. (1991) Geochronological evidence from discordant plutons for a late Proterozoic orogen in the Caledonides of Finnmark, northern Norway. *Journal of the Geological Society*, 148(1), 29-40.
- Furman, T. (2007) Geochemistry of East African Rift basalts: An overview. *Journal of African Earth Sciences*, 48, 147-160.
- Gill, J.B. (1976) Composition and age of Lau Basin and Ridge volcanic rocks: Implications for evolution of an interarc basin and remnant arc. *Geological Society of America Bulletin*, 87(10), 1384-1395.
- Pearce, J.A. (1982) Trace element characteristics of lavas from destructive plate boundaries. In: Thorpe R.S. (ed.), *Andesites*. Wiley, Chichester, 525-548.
- Putirka, K. (2016) Amphibole thermometers and barometers for igneous systems and some implications for eruption mechanisms of felsic magmas at arc volcanoes. *American Mineralogist*, 101(4), 841-858.
- Putnis, A. (1992) *Introduction to Mineral Sciences*. Press Syndicate of the University of Cambridge, Cambridge.
- Ramsay, D.M., Sturt, B.A., Zwaan, K.B., and Roberts, D. (1985) Caledonides of Northern Norway In *The Caledonian Orogen - Scandinavia and Related Areas* (eds. D. G. Gee and B. A. Sturt), p. 163-84. Wiley.

- Roberts, D. (2003) The Scandinavian Caledonides: event chronology, palaeogeographic settings and likely modern analogues. *Tectonophysics*, 365(1), 283-299.
- Roberts, R.J., Corfu, F., Torsvik, T.H., Ashwal, L.D., and Ramsay, D.M. (2006) Short-lived mafic magmatism at 560–570 Ma in the northern Norwegian Caledonides: U–Pb zircon ages from the Seiland Igneous Province. *Geological Magazine*, 143(6), 887-903.
- Schmidt, M.W. (1992) Amphibole composition in tonalite as a function of pressure: an experimental calibration of the Al-in-hornblende barometer. *Contributions to Mineralogy and Petrology*, 110(2), 304-310.
- Sturt, B.A., Pringle, I.R., and Ramsay, D.M. (1978) The Finnmarkian phase of the Caledonian Orogeny. *Journal of the Geological Society*, 135(6), 597-610.
- Sturt, B.A., Pringle, I.R., and Roberts, D. (1975) Caledonian Nappe Sequence of Finnmark, Northern Norway, and the Timing of Orogenic Deformation and Metamorphism.

APPENDIX A**BULK ROCK COMPOSITIONS**

Bulk rock compositions for samples from the Seiland Igneous Province.

Table A.1: Bulk Rock Compositions.

Sample	Rock Type	SiO₂	Al₂O₃	Fe₂O₃	MnO	MgO	CaO
RJR 238	Hornblendite	40.48	12.93	13.99	0.16	11.16	11.68
RJR 239	Hornblendite	40.56	12.94	14.04	0.16	11.30	11.71
RJR 240	Hornblendite	45.23	15.95	12.15	0.22	6.63	11.15
RJR 240(1)	Hornblendite	42.53	9.47	14.93	0.23	16.77	8.11
RJR 240(2)	Hornblendite	42.47	12.63	13.34	0.24	11.28	11.92
RJR 241	Gabbro	42.29	12.61	13.25	0.23	11.24	11.84
RJR 242(1)	Hornblendite	47.90	15.90	9.40	0.14	8.50	12.34
RJR 242(2)	Hornblendite	48.65	17.33	7.67	0.11	8.26	12.62
RJR 243	Gabbro	42.58	12.14	14.13	0.19	10.43	12.16
RJR 247	Hornblendite	40.47	12.87	14.04	0.16	11.25	11.75
RJR 244	Monzodiorite	58.76	21.13	5.48	0.25	0.23	1.97
RJR 245	Monzodiorite	62.50	18.62	4.99	0.06	0.18	0.83
RJR 246	Nepheline Monzonite	59.07	23.53	0.96	0.06	0.14	0.42

Table A.1: Continued.

Sample	Rock Type	Na	Mg	Al	Si	Ca	Sc
RJR 238	Hornblendite	2.23	67173.89	12.76	32.48	11.68	36.88
RJR 239	Hornblendite	2.27	67623.73	13.05	33.04	11.71	37.14
RJR 240	Hornblendite	3.50	39227.41	15.58	37.25	11.15	29.72
RJR 240(1)	Hornblendite	1.92	99973.37	9.61	35.92	8.11	23.72
RJR 240(2)	Hornblendite	2.35	68254.59	12.76	35.75	11.92	32.29
RJR 241	Gabbro	2.34	67169.42	12.50	35.45	11.84	31.86
RJR 242(1)	Hornblendite	2.67	50886.01	16.02	41.15	12.34	29.83
RJR 242(2)	Hornblendite	2.72	48888.58	17.34	42.55	12.62	26.06
RJR 243	Gabbro	2.29	63465.82	12.25	35.57	12.16	33.00
RJR 247	Hornblendite	2.34	68881.30	12.97	33.58	11.75	36.82
RJR 244	Monzodiorite	5.21	674.80	18.77	43.97	1.97	1.05
RJR 245	Monzodiorite	6.44	399.06	16.15	47.32	0.83	1.03
RJR 246	Nepheline Monzonite	7.36	235.45	20.02	43.19	0.42	0.86

Table A.1: Continued.

Sample	Rock Type	Ti	V	Ga⁶⁹	Ga⁷¹	Rb	Sr
RJR 238	Hornblendite	23542.0	422.99	25.60	15.74	11.39	473.62
RJR 239	Hornblendite	23837.2	426.28	24.33	15.66	11.37	471.70
RJR 240	Hornblendite	13113.4	241.50	19.75	15.01	9.23	585.70
RJR 240-1	Hornblendite	9924.12	177.19	18.95	12.10	44.44	328.37
RJR 240-2	Hornblendite	13228.6	267.14	22.52	14.39	20.92	366.00
RJR 241	Gabbro	13203.9	265.47	22.55	14.17	21.43	359.31
RJR 242-1	Hornblendite	8142.18	192.14	16.12	13.11	8.71	491.82
RJR 242-2	Hornblendite	6243.8	161.57	16.61	13.12	7.77	459.14
RJR 243	Gabbro	15808.7	285.21	20.31	16.64	6.94	390.47
RJR 247	Hornblendite	24145.7	446.95	25.32	16.53	11.47	480.72
RJR 244	Monzodiorite	1330.24	8.81	73.55	16.84	120.88	1026.84
RJR 245	Monzodiorite	1228.38	13.88	32.01	11.31	32.10	467.04
RJR 246	Nepheline Monzonite	522.01	8.37	17.02	15.11	82.67	69.10

Table A.1: Continued.

Sample	Rock Type	Y	Zr	Nb	Ba	La	Ce
RJR 238	Hornblendite	20.12	134.52	30.38	295.16	18.23	39.96
RJR 239	Hornblendite	19.99	134.30	30.36	293.86	18.10	39.84
RJR 240	Hornblendite	21.64	126.64	32.14	170.05	25.35	47.39
RJR 240-1	Hornblendite	14.92	164.62	29.89	253.91	24.41	45.56
RJR 240-2	Hornblendite	30.79	172.27	72.34	309.65	52.43	104.16
RJR 241	Gabbro	30.28	172.07	71.37	307.94	51.71	103.61
RJR 242-1	Hornblendite	13.28	77.12	10.17	110.13	8.61	18.87
RJR 242-2	Hornblendite	10.71	75.43	8.26	98.94	8.23	17.49
RJR 243	Gabbro	29.93	219.72	65.15	156.44	47.23	91.30
RJR 247	Hornblendite	19.68	133.25	30.89	301.27	18.17	40.80
RJR 244	Monzodiorite	29.31	457.61	193.96	1587.97	80.48	128.26
RJR 245	Monzodiorite	9.38	133.25	45.17	568.69	33.52	54.99
RJR 246	Nepheline Monzonite	7.13	241.62	78.98	75.39	12.47	21.49

Table A.1: Continued.

Sample	Rock Type	Pr	Nd	Sm	Eu	Gd
RJR 238	Hornblendite	6.05	28.30	6.82	2.15	6.57
RJR 239	Hornblendite	5.89	27.97	6.74	2.13	6.40
RJR 240	Hornblendite	6.12	26.02	5.57	1.83	5.34
RJR 240-1	Hornblendite	5.78	24.46	5.09	1.61	4.59
RJR 240-2	Hornblendite	12.38	47.41	8.47	2.44	7.24
RJR 241	Gabbro	12.27	47.30	8.52	2.41	7.13
RJR 242-1	Hornblendite	2.72	12.52	3.24	1.16	3.22
RJR 242-2	Hornblendite	2.35	10.51	2.55	0.93	2.55
RJR 243	Gabbro	11.43	46.16	9.37	2.70	8.26
RJR 247	Hornblendite	5.92	28.08	6.78	2.15	6.35
RJR 244	Monzodiorite	13.08	42.98	6.58	2.06	5.50
RJR 245	Monzodiorite	5.30	16.36	2.36	1.12	1.89
RJR 246	Nepheline Monzonite	2.16	6.85	1.05	0.73	0.89

Table A.1: Continued:

Sample	Rock Type	Tb	Dy	Er	Yb	Lu
RJR 238	Hornblendite	0.86	4.54	1.77	1.20	0.16
RJR 239	Hornblendite	0.84	4.51	1.73	1.21	0.15
RJR 240	Hornblendite	0.74	4.23	2.04	1.64	0.23
RJR 240-1	Hornblendite	0.60	3.27	1.35	0.95	0.14
RJR 240-2	Hornblendite	0.99	5.78	2.94	2.58	0.36
RJR 241	Gabbro	0.97	5.68	2.94	2.49	0.35
RJR 242-1	Hornblendite	0.47	2.69	1.27	0.97	0.14
RJR 242-2	Hornblendite	0.37	2.17	1.03	0.84	0.11
RJR 243	Gabbro	1.10	6.02	2.69	2.09	0.27
RJR 247	Hornblendite	0.83	4.49	1.77	1.20	0.15
RJR 244	Monzodiorite	0.78	4.87	2.95	3.10	0.49
RJR 245	Monzodiorite	0.26	1.61	0.97	0.96	0.14
RJR 246	Nepheline Monzonite	0.14	0.98	0.80	0.94	0.15

Table A.1: Continued.

Sample	Rock Type	Hf	Ta	Pb	Th	U
RJR 238	Hornblendite	3.98	1.81	2.10	1.66	0.48
RJR 239	Hornblendite	4.00	1.82	1.98	1.51	0.51
RJR 240	Hornblendite	3.05	1.98	2.81	2.20	0.51
RJR 240-1	Hornblendite	3.73	1.78	1.23	2.99	0.67
RJR 240-2	Hornblendite	3.85	3.55	2.24	7.55	1.00
RJR 241	Gabbro	3.81	3.50	2.09	7.59	1.00
RJR 242-1	Hornblendite	1.93	0.59	1.57	0.92	0.31
RJR 242-2	Hornblendite	1.83	0.49	1.33	1.07	0.28
RJR 243	Gabbro	5.21	3.38	2.96	5.84	0.91
RJR 247	Hornblendite	3.94	1.80	1.99	1.53	0.50
RJR 244	Monzodiorite	8.21	13.12	11.59	21.48	3.61
RJR 245	Monzodiorite	2.38	3.52	4.56	10.29	1.52
RJR 246	Nepheline Monzonite	3.14	9.93	4.57	6.39	17.68

APPENDIX B**HORNBLENDE COMPOSITIONS**

Hornblende compositions for the Seiland Igneous Complex. All abundances in table ABC.1 are in weight percent. All abundances in Table ABC.2 are listed in parts per million.

Table B.1: Hornblende major element compositions

Sample-Grain-Spot	Core/Rim	SiO₂	TiO₂	Al₂O₃	FeO
RJR238-AM1-A	Rim	45.06	1.93	12.40	16.55
RJR238-AM1-B	Inter	44.87	1.97	12.44	16.64
RJR238-AM1-C	Core	44.23	1.99	12.56	16.50
RJR238-AM1-D	Rim	45.33	1.64	11.81	16.27
RJR238-AM1-E	Core	45.28	1.80	11.94	16.66
RJR238-AM1-F	Rim	45.28	1.74	12.08	16.52
RJR238-AM1-G	Rim	45.01	1.90	12.04	16.40
RJR238-AM1-H	Core	44.92	2.01	11.98	16.38
RJR238-AM2-A	Inter	44.99	1.64	11.85	15.72
RJR238-AM2-B	Rim	45.44	1.72	11.67	15.95
RJR238-AM2-C	Core	45.18	1.78	11.83	16.04
RJR238-AM2-D	Core	45.19	1.76	12.25	15.78
RJR238-AM2-E	Rim	45.66	1.80	11.83	15.47
RJR238-AM3-A	Rim	44.04	1.74	12.43	16.77
RJR238-AM3-B	Rim	44.63	1.83	12.28	16.58
RJR238-AM3-C	Core	44.61	1.84	12.18	16.80
RJR238-AM3-D	Core	45.51	1.76	11.51	16.53
RJR238-AM3-E	Rim	45.63	1.79	11.43	16.46
RJR238-AM3-F	Inter	45.56	1.78	11.49	16.48
RJR238-AM3-G	Rim	45.61	1.72	11.48	16.51
RJR238-AM4-A	Rim	45.31	1.85	12.00	16.55
RJR238-AM4-B	Rim	45.39	1.88	12.01	16.32
RJR238-AM4-C	Inter	45.38	1.91	12.05	16.34
RJR238-AM4-D	Core	45.29	1.91	12.18	16.56
RJR238-AM4-E	Core	44.41	1.71	12.95	16.84
RJR238-AM4-F	Rim	45.41	1.71	11.38	16.86

Table B.1: Continued.

Sample-Grain-Spot	Core/Rim	SiO₂	TiO₂	Al₂O₃	FeO
RJR238-AM4-G	Rim	45.68	1.74	11.39	16.58
RJR238-AM4-H	Rim	45.19	1.80	11.49	16.76
RJR238-AM5-A	Rim	45.95	1.82	11.25	15.93
RJR238-AM5-B	Rim	45.43	1.77	11.62	15.68
RJR238-AM5-C	Rim	45.55	1.76	11.77	16.02
RJR238-AM5-D	Core	45.02	1.86	11.55	16.73
RJR238-AM5-E	Core	45.98	1.83	12.28	15.75
RJR238-AM5-F	Rim	46.00	1.73	12.23	15.30
RJR238-AM5-G	Rim	46.31	1.76	12.05	15.29
RJR238-AM5-H	Inter	46.10	1.85	11.89	15.57
RJR238-AM5-I	Rim	45.21	1.99	12.22	15.94
RJR238-AM5-J	Core	44.49	1.89	12.53	16.43
RJR238-AM6-A	Rim	1.58	1.08	12.34	13.88
RJR238-AM6-B	Rim	50.24	1.86	10.86	14.14
RJR238-AM6-C	Inter	49.51	1.82	10.80	13.84
RJR238-AM6-D	Rim	46.02	1.15	13.14	13.94
RJR238-AM6-E	Inter	46.43	1.17	12.93	14.05
RJR238-AM6-F	Core	46.71	1.44	12.91	14.20
RJR238-AM6-G	Core	49.03	1.92	11.25	13.91
RJR238-AM6-H	Rim	46.66	1.34	12.97	14.18
RJR239-AM1-A	Rim	49.62	bdl	8.99	11.98
RJR239-AM1-B	Rim	50.01	bdl	8.70	11.69
RJR239-AM1-C	Core	49.71	0.67	8.64	11.61
RJR239-AM1-D	Rim	49.41	0.68	8.82	11.47
RJR239-AM1-E	Inter	48.98	0.65	9.07	11.79
RJR239-AM1-F	Rim	49.60	0.65	8.77	11.63
RJR239-AM2-A	Rim	50.06	0.50	8.43	11.25
RJR239-AM2-B	Core	48.85	0.66	9.02	12.02
RJR239-AM2-C	Core	47.88	0.97	9.46	12.04
RJR239-AM2-D	Core	47.71	0.77	9.68	12.17
RJR239-AM2-E	Core	47.93	0.76	9.69	11.81
RJR239-AM2-F	Rim	49.38	0.65	8.54	11.61
RJR239-AM2-G	Rim	49.85	0.58	8.23	11.52
RJR239-AM2-H	Inter	49.85	0.51	8.48	11.52
RJR239-AM2-I	Inter	47.93	0.72	9.77	12.15

Table B.1: Continued.

Sample-Grain-Spot	Core/Rim	SiO₂	TiO₂	Al₂O₃	FeO
RJR239-AM2-J	Rim	48.42	0.64	9.31	12.02
RJR239-AM3-A	Rim	41.76	0.90	11.45	18.20
RJR239-AM3-B	Rim	41.76	0.90	11.45	18.20
RJR239-AM3-C	Core	40.45	0.84	9.73	16.89
RJR239-AM3-E	Rim	44.93	1.20	13.32	10.95
RJR239-AM3-H	Inter	43.84	1.16	13.79	11.30
RJR239-AM3-I	Rim	44.58	1.09	12.87	11.47
RJR239-AM3-J	Core	44.63	1.06	13.03	11.40
RJR240-AM1-A	Rim	43.57	2.02	12.97	15.45
RJR240-AM1-B	Core	44.34	2.22	12.75	15.71
RJR240-AM1-C	Core	43.00	2.23	13.68	15.76
RJR240-AM1-D	Rim	43.47	2.04	13.26	15.35
RJR240-AM1-E	Rim	45.02	1.62	12.74	15.40
RJR240-AM2-A	Rim	44.07	2.06	12.62	14.81
RJR240-AM2-B	Core	45.42	1.60	11.83	15.02
RJR240-AM2-C	Core	44.62	1.89	12.10	15.14
RJR240-AM2-D	Inter	43.72	1.83	12.68	15.35
RJR240-AM3-A	Rim	45.16	1.63	11.85	14.92
RJR240-AM3-B	Rim	45.72	2.01	12.81	14.72
RJR240-AM3-C	Core	42.56	2.36	13.33	15.50
RJR240-AM3-D	Core	40.95	6.17	12.48	17.21
RJR240-AM3-E	Inter	43.83	1.99	13.65	15.42
RJR240-AM3-F	Rim	44.35	2.25	13.35	14.69
RJR240-AM3-G	Core	44.68	2.12	12.80	15.54
RJR240-AM4-A	Rim	44.38	1.83	12.85	15.11
RJR240-AM4-B	Core	44.12	2.01	13.34	14.85
RJR240-AM4-C	Rim	44.84	2.17	11.90	15.17
RJR240-AM5-A	Rim	43.94	1.98	13.40	14.89
RJR240-AM5-B	Inter	43.14	2.10	13.47	15.43
RJR240-AM5-D	Rim	44.54	1.88	13.27	15.15
RJR240-AM5-E	Core	43.68	2.12	13.42	15.37
RJR240-AM5-F	Inter	43.89	2.14	13.11	15.43
RJR240-AM5-G	Rim	44.17	1.93	13.33	15.00
RJR240-AM6-A	Rim	47.17	1.90	12.48	13.56
RJR240-AM6-B	Rim	46.05	1.75	13.08	13.14

Table B.1: Continued.

Sample-Grain-Spot	Core/Rim	SiO₂	TiO₂	Al₂O₃	FeO
RJR240-AM6-C	Rim	45.73	1.75	13.06	13.59
RJR240-AM6-D	Rim	45.19	2.05	12.81	14.51
RJR240-AM6-E	Inter	46.06	1.89	12.10	14.66
RJR240-AM6-F	Rim	46.00	1.76	12.82	13.71
RJR240-AM6-G	Core	45.71	2.04	12.45	12.24
RJR240-AM6-H	Core	44.09	2.87	12.71	15.42
RJR240-AM6-I	Core	43.04	3.02	11.45	17.63
RJR240-AM7-A	Rim	45.36	1.99	13.11	14.37
RJR240-AM7-B	Inter	45.63	1.71	12.48	14.20
RJR240-AM7-C	Core	44.83	2.02	13.10	14.56
RJR240-AM7-D	Rim	43.07	1.78	13.65	14.98
RJR241-AM2-A	Core	43.61	1.32	15.31	13.20
RJR241-AM2-B	Core	43.30	1.21	15.79	13.20
RJR241-AM2-C	Core	43.02	0.81	16.66	13.02
RJR241-AM2-D	Rim	43.48	bdl	16.95	12.59
RJR241-AM2-E	Rim	43.48	bdl	16.95	12.59
RJR241-AM3-A	Rim	49.26	1.08	8.24	10.51
RJR241-AM3-B	Rim	45.87	1.59	12.24	12.92
RJR241-AM3-C	Core	42.78	0.89	10.37	17.90
RJR241-AM3-D	Inter	50.68	0.90	6.60	9.41
RJR241-AM4-A	Rim	53.39	0.35	3.68	7.42
RJR241-AM4-B	Core	53.63	bdl	3.53	7.69
RJR241-AM4-C	Inter	53.22	0.43	4.42	8.30
RJR241-AM4-D	Core	53.58	bdl	4.05	8.25
RJR241-AM4-E	Rim	52.39	0.51	5.40	8.64
RJR242-AM1-A	Rim	44.26	1.90	12.24	15.31
RJR242-AM1-B	Core	44.42	1.80	12.21	15.27
RJR242-AM1-D	Inter	44.26	1.85	12.17	15.11
RJR242-AM2-A	Rim	44.45	1.80	12.67	14.42
RJR242-AM2-B	Core	44.52	1.87	12.35	14.82
RJR242-AM2-C	Rim	44.31	1.94	12.39	14.73
RJR242-AM4-A	Rim	44.12	1.95	12.29	15.16
RJR242-AM4-B	Core	44.04	1.87	12.39	15.17
RJR242-AM4-C	Rim	44.13	1.88	12.33	15.14
RJR243-AM1-A	Rim	48.29	1.12	10.16	12.91

Table B.1: Continued.

Sample-Grain-Spot	Core/Rim	SiO₂	TiO₂	Al₂O₃	FeO
RJR243-AM1-B	Core	47.14	1.19	11.14	13.18
RJR243-AM1-C	Core	46.10	0.88	12.49	13.35
RJR243-AM1-D	Rim	45.70	0.84	13.23	13.65
RJR243-AM3-A	Rim	42.76	bdl	15.89	16.36
RJR243-AM3-B	Core	44.16	bdl	14.47	16.13
RJR243-AM3-C	Core	46.16	bdl	13.29	15.98
RJR243-AM3-D	Rim	47.65	bdl	11.93	15.26
RJR245-AM1-A	Inter	38.74	1.19	9.19	34.74
RJR245-AM1-B	Rim	38.74	1.19	9.19	34.74
RJR245-AM1-C	Core	38.26	1.33	8.93	33.93
RJR245-AM1-D	Rim	37.73	1.30	9.11	34.13
RJR245-AM1-E	Rim	37.89	1.36	9.14	33.73
RJR245-AM2-A	Core	38.44	1.38	9.12	33.67
RJR245-AM2-B	Rim	38.44	1.38	9.12	33.67
RJR245-AM2-C	Core	36.66	1.55	10.58	35.20
RJR245-AM2-D	Core	37.36	1.34	9.66	34.83
RJR245-AM2-E	Rim	37.49	1.46	9.49	34.39
RJR245-AM2-F	Core	37.75	1.30	9.50	34.20
RJR245-AM4-A	Rim	37.19	1.00	9.44	34.48
RJR245-AM4-B	Rim	37.44	1.09	9.42	34.03
RJR245-AM4-C	Core	37.95	1.25	8.90	34.14
RJR245-AM4-D	Rim	38.02	1.23	8.99	34.08

Table B.1: Continued.

Sample-Grain-Spot	Core/Rim	MgO	CaO	Na₂O	K₂O
RJR238-AM1-A	Rim	8.83	12.28	1.62	0.97
RJR238-AM1-B	Inter	8.77	12.28	1.62	1.00
RJR238-AM1-C	Core	8.91	12.24	1.98	1.12
RJR238-AM1-D	Rim	9.72	12.08	1.83	0.92
RJR238-AM1-E	Core	9.24	12.23	1.52	0.91
RJR238-AM1-F	Rim	9.26	12.40	1.43	0.92
RJR238-AM1-G	Rim	9.23	12.63	1.48	0.90
RJR238-AM1-H	Core	9.12	12.86	1.41	0.90
RJR238-AM2-A	Inter	9.96	12.28	2.11	1.03
RJR238-AM2-B	Rim	9.79	12.20	1.85	1.00
RJR238-AM2-C	Core	9.68	12.31	1.78	1.01
RJR238-AM2-D	Core	9.70	12.49	1.61	0.88
RJR238-AM2-E	Rim	9.87	12.38	1.76	0.90
RJR238-AM3-A	Rim	9.51	12.38	1.90	0.89
RJR238-AM3-B	Rim	9.27	12.54	1.58	0.92
RJR238-AM3-C	Core	9.29	12.42	1.58	0.93
RJR238-AM3-D	Core	9.47	12.48	1.50	0.88
RJR238-AM3-E	Rim	9.55	12.40	1.53	0.87
RJR238-AM3-F	Inter	9.55	12.37	1.55	0.87
RJR238-AM3-G	Rim	9.52	12.35	1.58	0.86
RJR238-AM4-A	Rim	9.28	12.30	1.45	0.89
RJR238-AM4-B	Rim	9.34	12.24	1.58	0.89
RJR238-AM4-C	Inter	9.34	12.16	1.56	0.91
RJR238-AM4-D	Core	9.11	12.20	1.45	0.94
RJR238-AM4-E	Core	8.69	12.32	1.56	0.99
RJR238-AM4-F	Rim	9.63	12.19	1.65	0.76
RJR238-AM4-G	Rim	9.60	12.24	1.62	0.78
RJR238-AM4-H	Rim	9.35	12.47	1.44	1.02
RJR238-AM5-A	Rim	9.74	12.35	1.59	0.97
RJR238-AM5-B	Rim	9.97	12.29	1.95	0.92
RJR238-AM5-C	Rim	9.61	12.48	1.57	0.89
RJR238-AM5-D	Core	9.16	13.05	1.31	0.94
RJR238-AM5-E	Core	8.98	12.04	1.64	1.09
RJR238-AM5-F	Rim	9.46	11.81	2.11	1.01
RJR238-AM5-G	Rim	9.40	11.93	1.96	0.98

Table B.1: Continued.

Sample-Grain-Spot	Core/Rim	MgO	CaO	Na₂O	K₂O
RJR238-AM5-H	Inter	9.36	12.00	1.89	1.00
RJR238-AM5-I	Rim	9.37	12.39	1.61	0.90
RJR238-AM5-J	Core	9.29	12.22	1.85	0.94
RJR238-AM6-A	Rim	9.96	11.78	1.58	0.91
RJR238-AM6-B	Rim	10.12	11.52	bdl	0.91
RJR238-AM6-C	Inter	9.81	11.23	1.82	0.85
RJR238-AM6-D	Rim	10.40	11.79	2.12	0.99
RJR238-AM6-E	Inter	10.30	11.82	1.94	0.95
RJR238-AM6-F	Core	9.91	11.72	1.80	0.98
RJR238-AM6-G	Core	9.68	11.24	1.80	0.85
RJR238-AM6-H	Rim	9.95	11.88	1.72	0.93
RJR239-AM1-A	Rim	15.07	12.42	1.92	bdl
RJR239-AM1-B	Rim	15.26	12.41	1.94	bdl
RJR239-AM1-C	Core	15.13	12.34	1.89	bdl
RJR239-AM1-D	Rim	14.95	12.29	2.02	0.36
RJR239-AM1-E	Inter	14.82	12.33	1.96	0.39
RJR239-AM1-F	Rim	15.08	12.39	1.88	bdl
RJR239-AM2-A	Rim	15.33	12.16	1.95	0.32
RJR239-AM2-B	Core	14.97	12.02	2.13	0.33
RJR239-AM2-C	Core	14.91	12.38	2.20	bdl
RJR239-AM2-D	Core	14.63	12.56	2.10	0.39
RJR239-AM2-E	Core	14.79	12.49	2.18	0.35
RJR239-AM2-F	Rim	15.25	12.08	2.09	0.40
RJR239-AM2-G	Rim	15.41	12.03	2.03	0.35
RJR239-AM2-H	Inter	15.25	12.22	1.91	0.28
RJR239-AM2-I	Inter	14.54	12.23	2.13	0.36
RJR239-AM2-J	Rim	14.85	12.15	2.16	0.31
RJR239-AM3-A	Rim	18.64	5.28	1.27	2.49
RJR239-AM3-B	Rim	18.64	5.28	1.27	2.49
RJR239-AM3-C	Core	16.00	7.29	1.32	1.81
RJR239-AM3-E	Rim	18.23	3.64	1.45	6.28
RJR239-AM3-H	Inter	18.93	2.50	1.55	6.93
RJR239-AM3-I	Rim	18.14	4.49	1.74	5.62
RJR239-AM3-J	Core	18.17	4.27	1.65	5.80
RJR240-AM1-A	Rim	9.84	12.56	1.90	1.20

Table B.1: Continued.

Sample-Grain-Spot	Core/Rim	MgO	CaO	Na₂O	K₂O
RJR240-AM1-B	Core	9.47	12.32	1.63	1.07
RJR240-AM1-C	Core	9.38	12.48	1.74	1.24
RJR240-AM1-D	Rim	9.59	12.39	2.13	1.32
RJR240-AM1-E	Rim	9.66	11.96	2.23	1.37
RJR240-AM2-A	Rim	9.92	12.74	2.21	1.25
RJR240-AM2-B	Core	10.27	12.35	2.11	1.09
RJR240-AM2-C	Core	10.50	12.15	2.30	0.99
RJR240-AM2-D	Inter	10.22	12.57	2.19	1.07
RJR240-AM3-A	Rim	13.32	10.11	1.65	1.02
RJR240-AM3-B	Rim	9.03	11.65	2.14	1.45
RJR240-AM3-C	Core	9.65	12.07	2.28	1.21
RJR240-AM3-D	Core	8.70	11.32	1.80	1.18
RJR240-AM3-E	Inter	9.48	12.37	1.84	1.18
RJR240-AM3-F	Rim	9.54	11.96	2.33	1.32
RJR240-AM3-G	Core	9.22	12.20	1.89	1.29
RJR240-AM4-A	Rim	9.66	12.61	2.10	1.21
RJR240-AM4-B	Core	9.44	12.80	2.07	1.16
RJR240-AM4-C	Rim	8.82	12.75	2.32	1.70
RJR240-AM5-A	Rim	9.95	12.26	2.15	1.12
RJR240-AM5-B	Inter	9.67	12.67	2.06	1.22
RJR240-AM5-D	Rim	9.43	12.30	1.91	1.27
RJR240-AM5-E	Core	9.62	12.52	2.03	1.23
RJR240-AM5-F	Inter	9.81	12.53	1.95	0.91
RJR240-AM5-G	Rim	9.83	12.45	1.93	1.11
RJR240-AM6-A	Rim	9.24	11.64	1.90	1.34
RJR240-AM6-B	Rim	9.99	11.50	2.78	1.41
RJR240-AM6-C	Rim	9.96	11.56	2.70	1.41
RJR240-AM6-D	Rim	9.89	11.89	2.31	1.09
RJR240-AM6-E	Inter	9.85	11.89	2.27	1.28
RJR240-AM6-F	Rim	10.20	11.91	2.23	1.37
RJR240-AM6-G	Core	10.06	11.47	2.44	1.59
RJR240-AM6-H	Core	9.36	11.81	2.22	1.51
RJR240-AM6-I	Core	10.81	11.03	1.61	1.42
RJR240-AM7-A	Rim	9.55	12.10	2.08	1.15
RJR240-AM7-B	Inter	10.28	11.42	2.76	1.27

Table B.1: Continued.

Sample-Grain-Spot	Core/Rim	MgO	CaO	Na₂O	K₂O
RJR240-AM7-C	Core	9.80	12.04	2.30	1.36
RJR240-AM7-D	Rim	10.01	12.42	2.62	1.12
RJR241-AM2-A	Core	10.93	12.72	12.72	0.91
RJR241-AM2-B	Core	10.83	12.74	1.99	0.94
RJR241-AM2-C	Core	10.80	12.75	1.92	1.00
RJR241-AM2-D	Rim	11.13	12.87	1.93	1.05
RJR241-AM2-E	Rim	11.13	12.87	1.93	1.05
RJR241-AM3-A	Rim	11.95	17.41	1.12	0.43
RJR241-AM3-B	Rim	11.83	13.00	1.84	0.71
RJR241-AM3-C	Core	16.99	7.74	1.40	1.93
RJR241-AM3-D	Inter	12.05	19.21	0.83	0.32
RJR241-AM4-A	Rim	12.53	22.63	bdl	bdl
RJR241-AM4-B	Core	12.45	22.71	bdl	bdl
RJR241-AM4-C	Inter	12.62	21.00	bdl	bdl
RJR241-AM4-D	Core	12.56	21.56	bdl	bdl
RJR241-AM4-E	Rim	12.45	20.32	bdl	0.29
RJR242-AM1-A	Rim	10.42	12.82	1.77	0.97
RJR242-AM1-B	Core	10.49	12.77	1.74	0.99
RJR242-AM1-D	Inter	10.68	12.64	2.03	0.97
RJR242-AM2-A	Rim	10.95	12.39	2.16	0.89
RJR242-AM2-B	Core	10.63	12.70	1.89	0.93
RJR242-AM2-C	Rim	10.71	12.68	1.99	0.94
RJR242-AM4-A	Rim	10.43	12.50	2.10	1.08
RJR242-AM4-B	Core	10.41	12.64	2.07	1.07
RJR242-AM4-C	Rim	10.47	12.66	2.02	1.03
RJR243-AM1-A	Rim	12.88	12.76	1.49	0.38
RJR243-AM1-B	Core	12.36	12.84	1.66	0.49
RJR243-AM1-C	Core	12.03	12.80	1.88	0.46
RJR243-AM1-D	Rim	11.51	12.96	1.61	0.51
RJR243-AM3-A	Rim	9.63	12.75	1.67	0.79
RJR243-AM3-B	Core	10.21	12.71	1.56	0.66
RJR243-AM3-C	Core	10.87	13.01	bdl	0.60
RJR243-AM3-D	Rim	11.76	12.89	bdl	0.51
RJR245-AM1-A	Inter	1.44	10.59	0.82	1.99
RJR245-AM1-B	Rim	1.44	10.59	0.82	1.99

Table B.1: Continued.

Sample-Grain-Spot	Core/Rim	MgO	CaO	Na₂O	K₂O
RJR245-AM1-C	Core	1.40	10.53	0.74	2.10
RJR245-AM1-D	Rim	1.43	10.46	0.80	2.12
RJR245-AM1-E	Rim	1.47	10.56	0.83	2.13
RJR245-AM2-A	Core	1.51	10.49	0.86	2.00
RJR245-AM2-B	Rim	1.51	10.49	0.86	2.00
RJR245-AM2-C	Core	1.57	7.44	0.42	4.10
RJR245-AM2-D	Core	1.52	10.05	0.74	1.96
RJR245-AM2-E	Rim	1.46	10.18	0.82	2.02
RJR245-AM2-F	Core	1.56	10.28	0.86	1.98
RJR245-AM4-A	Rim	1.32	10.48	0.68	2.17
RJR245-AM4-B	Rim	1.54	10.43	0.96	2.08
RJR245-AM4-C	Core	1.55	10.45	0.83	2.09
RJR245-AM4-D	Rim	1.62	10.42	0.92	2.04

Table B.2: Hornblende trace element abundances

Sample-Grain-Spot	Core/Rim	Li	Mg	Al	Si	P	Ca
RJR238-AM1-A	Rim	14.01	83922.98	15.67	46.29	117.53	12.28
RJR238-AM1-B	Inter	15.46	84002.79	16.38	47.21	322.71	12.28
RJR238-AM1-C	Core	14.01	82320.77	16.30	45.35	149.85	12.24
RJR238-AM1-D	Rim	10.24	84359.05	14.59	45.12	33.95	12.08
RJR238-AM1-E	Core	13.46	80272.69	16.13	44.42	26.88	12.23
RJR238-AM1-F	Rim	11.51	83614.08	15.53	45.89	50.51	12.40
RJR238-AM1-G	Rim	11.28	86005.21	15.49	47.10	29.68	12.63
RJR238-AM1-H	Core	12.76	84799.81	16.32	46.23	238.23	12.86
RJR238-AM2-A	Inter	9.28	84585.97	14.35	44.44	25.41	12.28
RJR238-AM2-B	Rim	8.96	84847.89	14.00	45.01	126.70	12.20
RJR238-AM2-C	Core	12.90	91360.02	16.12	47.09	311.60	12.31
RJR238-AM2-D	Core	9.74	82171.67	15.63	43.62	158.18	12.49
RJR238-AM2-E	Rim	10.09	86785.70	14.52	45.19	42.03	12.38
RJR238-AM3-A	Rim	12.02	82043.19	15.63	45.14	19.75	12.38
RJR238-AM3-B	Rim	12.02	81985.21	15.58	45.34	18.75	12.54
RJR238-AM3-C	Core	11.28	81663.64	15.27	44.41	48.04	12.42
RJR238-AM3-D	Core	10.53	83091.18	14.86	45.09	40.65	12.48
RJR238-AM3-E	Rim	11.06	84370.72	14.74	45.74	29.34	12.40
RJR238-AM3-F	Inter	9.95	81477.59	14.87	44.89	183.89	12.37
RJR238-AM3-G	Rim	9.74	81988.85	14.72	44.94	44.52	12.35
RJR238-AM4-A	Rim	10.27	82512.97	15.15	46.23	20.93	12.30
RJR238-AM4-B	Rim	9.35	83604.23	15.24	46.55	20.18	12.24
RJR238-AM4-C	Inter	12.99	85053.04	15.81	46.28	30.68	12.16
RJR238-AM4-D	Core	15.26	81302.19	16.70	44.91	247.54	12.20
RJR238-AM4-E	Core	12.97	76697.04	16.36	44.80	152.42	12.32
RJR238-AM4-F	Rim	10.45	83215.22	14.49	46.13	43.15	12.19
RJR238-AM4-G	Rim	8.79	83582.02	14.53	46.31	27.75	12.24
RJR238-AM4-H	Rim	10.01	84958.28	15.31	47.09	25.72	12.47
RJR238-AM5-A	Rim	10.60	86545.07	14.73	47.51	35.40	12.35
RJR238-AM5-B	Rim	11.52	85674.30	14.83	47.11	49.66	12.29
RJR238-AM5-C	Rim	14.01	90903.04	16.35	48.26	186.21	12.48
RJR238-AM5-D	Core	13.77	85742.89	16.93	48.42	30.46	13.05
RJR238-AM5-E	Core	13.83	77726.75	16.08	44.79	125.95	12.04
RJR238-AM5-F	Rim	13.42	80421.57	15.09	43.86	75.82	11.81

Table B.2: Continued.

Sample-Grain-Spot	Core/Rim	Li	Mg	Al	Si	P	Ca
RJR238-AM5-G	Rim	12.45	79775.76	14.61	45.00	133.87	11.93
RJR238-AM5-H	Inter	12.28	79694.43	14.97	44.41	77.78	12.00
RJR238-AM5-I	Rim	12.17	81651.54	15.58	46.59	212.21	12.39
RJR238-AM5-J	Core	14.81	74459.91	16.45	43.46	315.78	12.22
RJR238-AM6-A	Rim	8.61	83477.87	15.54	43.94	13.80	11.78
RJR238-AM6-B	Rim	8.91	83607.79	13.80	44.19	22.16	11.52
RJR238-AM6-C	Inter	10.27	81332.40	13.61	44.19	128.71	11.23
RJR238-AM6-D	Rim	10.74	85416.41	16.41	44.58	33.60	11.79
RJR238-AM6-E	Inter	10.20	90919.27	15.88	45.16	54.94	11.82
RJR238-AM6-F	Core	12.78	81531.62	16.85	43.24	223.13	11.72
RJR238-AM6-G	Core	13.64	78082.99	15.48	41.62	260.39	11.24
RJR238-AM6-H	Rim	9.99	89109.68	15.94	45.64	38.06	11.88
RJR239-AM1-A	Rim	4.59	139887.34	10.78	57.04	107.84	12.42
RJR239-AM1-B	Rim	4.17	143371.20	10.71	55.63	53.32	12.41
RJR239-AM1-C	Core	3.98	135053.50	11.51	52.43	40.65	12.34
RJR239-AM1-D	Rim	3.93	135891.22	11.81	55.28	85.97	12.27
RJR239-AM1-E	Inter	3.18	127723.35	11.24	50.75	96.95	12.33
RJR239-AM1-F	Rim	3.48	132110.36	10.67	51.96	44.37	12.39
RJR239-AM2-A	Rim	3.07	136624.29	11.25	53.46	42.43	12.16
RJR239-AM2-B	Core	3.56	130692.11	11.55	50.99	169.20	12.02
RJR239-AM2-C	Core	2.94	139448.00	11.67	53.11	51.36	12.38
RJR239-AM2-D	Core	2.68	125196.77	12.98	50.06	123.98	12.56
RJR239-AM2-E	Core	3.34	140045.19	11.28	53.41	37.58	12.49
RJR239-AM2-F	Rim	3.45	143196.78	10.46	53.80	151.23	12.08
RJR239-AM2-G	Rim	3.38	145309.69	10.32	55.42	42.61	12.03
RJR239-AM2-H	Inter	2.88	136833.15	11.40	53.14	172.38	12.22
RJR239-AM2-I	Inter	3.38	133056.50	11.93	50.65	147.78	12.23
RJR239-AM2-J	Rim	3.24	138999.38	10.06	53.07	45.10	12.15
RJR239-AM3-A	Rim	1.07	58202.52	4.79	22.66	21.80	5.28
RJR239-AM3-B	Rim	1.41	57226.02	5.06	23.06	20.83	5.28
RJR239-AM3-C	Core	1.51	81316.43	5.96	32.25	33.61	7.29
RJR239-AM3-E	Rim	0.25	13489.65	1.01	5.30	4.73	1.20
RJR239-AM3-H	Inter	0.51	25132.64	2.64	10.32	59.08	2.50
RJR239-AM3-I	Rim	0.96	46473.56	4.42	18.70	64.52	4.49

Table B.2: Continued.

Sample-Grain-Spot	Core/Rim	Li	Mg	Al	Si	P	Ca
RJR239-AM3-J	Core	5.25	65553.64	6.45	24.30	62.03	4.27
RJR240-AM1-A	Rim	6.82	86784.63	16.22	44.74	30.28	12.56
RJR240-AM1-B	Core	6.92	83038.41	15.69	44.11	24.11	12.32
RJR240-AM1-C	Core	7.64	83457.59	17.30	44.79	138.49	12.48
RJR240-AM1-D	Rim	7.42	82988.97	16.99	45.47	104.48	12.39
RJR240-AM1-E	Rim	6.72	76095.60	14.95	41.86	54.24	11.96
RJR240-AM2-A	Rim	6.68	83631.27	16.24	44.54	63.70	12.74
RJR240-AM2-B	Core	5.80	85962.19	14.55	45.02	76.68	12.35
RJR240-AM2-C	Core	5.55	84602.47	14.41	44.30	26.04	12.15
RJR240-AM2-D	Inter	6.58	88171.68	15.61	45.77	31.69	12.57
RJR240-AM3-A	Rim	5.99	68324.36	14.84	35.75	27.16	10.11
RJR240-AM3-B	Rim	6.97	78770.98	15.79	41.33	26.47	11.65
RJR240-AM3-C	Core	6.76	81884.97	16.39	43.49	186.74	12.07
RJR240-AM3-D	Core	6.41	74306.53	15.58	39.21	176.38	11.32
RJR240-AM3-E	Inter	6.86	82094.96	17.07	43.37	28.78	12.37
RJR240-AM3-F	Rim	6.68	79809.91	16.64	43.18	73.32	11.96
RJR240-AM3-G	Core	7.04	79703.15	16.62	42.95	167.51	12.20
RJR240-AM4-A	Rim	6.91	86005.50	17.61	44.69	44.59	12.61
RJR240-AM4-B	Core	7.18	90789.48	17.70	47.31	158.28	12.80
RJR240-AM4-C	Rim	5.18	67397.30	13.20	35.02	32.55	9.88
RJR240-AM5-A	Rim	6.88	82748.28	16.53	44.01	17.15	12.26
RJR240-AM5-B	Inter	7.59	87422.74	17.68	45.73	48.14	12.67
RJR240-AM5-D	Rim	7.94	85615.06	17.42	44.63	22.34	12.30
RJR240-AM5-E	Core	7.70	89822.17	17.57	45.06	145.53	12.52
RJR240-AM5-F	Inter	7.83	89551.85	16.94	44.95	17.31	12.53
RJR240-AM5-G	Rim	7.64	85231.17	16.63	42.91	15.46	12.45
RJR240-AM6-A	Rim	6.35	76655.34	15.58	42.13	26.91	11.64
RJR240-AM6-B	Rim	6.35	76161.97	15.70	41.17	132.28	11.50
RJR240-AM6-C	Rim	6.30	54044.52	5.76	94.81	86.43	11.56
RJR240-AM6-D	Rim	6.52	80155.71	15.85	43.85	35.33	11.89
RJR240-AM6-E	Inter	6.20	82016.58	15.50	42.07	18.60	11.89
RJR240-AM6-F	Rim	6.64	81491.55	16.04	43.32	37.10	11.91
RJR240-AM6-G	Core	6.54	72785.66	15.06	40.16	142.12	11.47

Table B.2: Continued.

Sample-Grain-Spot	Core/Rim	Li	Mg	Al	Si	P	Ca
RJR240-AM6-H	Core	6.76	79307.41	16.30	42.66	223.22	11.81
RJR240-AM6-I	Core	6.53	73875.14	15.29	39.87	226.58	11.03
RJR240-AM7-A	Rim	7.31	85589.26	16.68	42.76	13.44	12.10
RJR240-AM7-B	Inter	7.08	84623.92	15.77	41.55	20.00	11.42
RJR240-AM7-C	Core	7.23	86954.16	16.97	43.12	126.54	12.04
RJR240-AM7-D	Rim	7.19	90177.00	17.31	41.79	97.60	12.42
RJR241-AM2-A	Core	6.55	103730.09	14.29	51.03	64.53	12.72
RJR241-AM2-B	Core	6.80	106024.51	18.65	49.67	333.53	12.74
RJR241-AM2-C	Core	5.69	107909.34	15.25	51.38	194.57	12.75
RJR241-AM2-D	Rim	8.55	117988.40	18.29	52.48	72.88	12.87
RJR241-AM2-E	Rim	9.91	103614.75	21.42	49.15	155.19	12.87
RJR241-AM3-A	Rim	10.10	92462.35	5.02	45.90	25.02	17.41
RJR241-AM3-B	Rim	4.90	98906.78	13.01	46.59	27.39	13.00
RJR241-AM3-C	Core	10.41	98157.67	4.74	47.77	10.92	19.03
RJR241-AM3-D	Inter	10.14	95059.99	4.64	47.56	23.81	19.21
RJR241-AM4-A	Rim	10.07	155337.80	25.13	75.73	76.91	22.63
RJR241-AM4-B	Core	10.73	107605.32	4.92	56.92	22.17	22.71
RJR241-AM4-C	Inter	12.80	112763.03	4.07	53.11	21.27	21.55
RJR241-AM4-D	Core	11.30	111806.03	4.83	56.06	36.33	21.56
RJR241-AM4-E	Rim	5.98	174236.39	23.75	76.89	77.07	20.32
RJR242-AM1-A	Rim	8.43	68120.69	15.10	46.31	135.28	12.82
RJR242-AM1-B	Core	8.29	75129.41	14.84	47.28	377.76	12.77
RJR242-AM1-D	Inter	8.18	78928.32	14.58	47.50	37.28	12.67
RJR242-AM2-A	Rim	8.83	80320.21	14.52	46.23	43.27	12.39
RJR242-AM2-B	Core	9.24	85173.77	15.47	48.35	84.63	12.70
RJR242-AM2-C	Rim	9.00	83867.58	15.05	47.82	248.01	12.68
RJR242-AM4-A	Rim	10.10	84001.01	14.81	46.70	231.47	12.50
RJR242-AM4-B	Core	10.23	86574.46	15.16	47.45	217.45	12.64
RJR242-AM4-C	Rim	12.02	89472.16	15.15	48.50	221.40	12.66
RJR243-AM1-A	Rim	5.93	95899.31	13.18	48.17	349.17	12.76
RJR243-AM1-B	Core	6.06	84320.23	13.30	50.53	117.53	12.84
RJR243-AM1-C	Core	8.24	81634.45	15.49	49.31	172.74	12.80
RJR243-AM1-D	Rim	20.57	66986.29	20.36	44.70	38.72	12.96
RJR243-AM3-A	Rim	12.02	69156.64	19.10	46.09	59.14	12.75
RJR243-AM3-B	Core	7.96	80802.73	14.87	50.45	40.35	12.71

Table B.2: Continued.

Sample-Grain-Spot	Core/Rim	Li	Mg	Al	Si	P	Ca
RJR243-AM3-C	Core	6.39	87604.17	12.10	53.06	45.30	13.01
RJR243-AM3-D	Rim	6.74	80950.63	13.57	51.40	83.41	12.89
RJR245-AM1-A	Inter	14.25	13872.96	11.32	40.15	23.62	10.59
RJR245-AM1-B	Rim	14.34	12931.17	11.25	40.85	22.96	10.59
RJR245-AM1-C	Core	10.54	14629.06	11.26	42.36	20.56	10.53
RJR245-AM1-D	Rim	7.95	13083.61	11.18	39.90	16.48	10.46
RJR245-AM1-E	Rim	19.77	13703.72	11.30	39.89	15.35	10.56
RJR245-AM2-A	Core	10.36	12217.59	10.71	38.83	19.21	10.40
RJR245-AM2-B	Rim	30.55	19772.09	13.12	61.29	36.94	10.49
RJR245-AM2-C	Core	421.16	37001.81	45.68	132.39	77.93	7.44
RJR245-AM2-D	Core	18.17	13783.74	11.18	39.68	30.59	10.05
RJR245-AM2-E	Rim	178.52	29446.26	22.11	73.43	82.24	10.18
RJR245-AM2-F	Core	11.38	14249.86	11.00	39.75	28.04	10.28
RJR245-AM4-A	Rim	14.01	12190.42	11.49	39.28	21.00	10.48
RJR245-AM4-B	Rim	20.56	13603.20	11.15	39.89	19.94	10.43
RJR245-AM4-C	Core	10.06	14447.58	11.08	40.69	23.76	10.45
RJR245-AM4-D	Rim	14.68	16305.55	11.38	42.22	28.11	10.42

Table B.2: Continued.

Sample-Grain-Spot	Core/Rim	Sc	Ti	V	Cr	Mn
RJR238-AM1-A	Rim	35.85	11727.33	322.92	442.70	1414.55
RJR238-AM1-B	Inter	36.39	19623.41	374.23	130.69	1592.24
RJR238-AM1-C	Core	31.92	11851.31	419.62	277.11	1391.91
RJR238-AM1-D	Rim	33.89	10919.20	275.61	496.47	1339.15
RJR238-AM1-E	Core	32.23	11903.71	388.87	371.83	1334.17
RJR238-AM1-F	Rim	30.25	11517.44	294.24	407.58	1362.84
RJR238-AM1-G	Rim	32.74	11715.85	293.55	307.93	1383.62
RJR238-AM1-H	Core	35.29	12038.99	413.40	427.92	1430.49
RJR238-AM2-A	Inter	38.20	10681.77	269.17	650.23	1267.28
RJR238-AM2-B	Rim	41.52	10909.77	271.47	641.88	1266.62
RJR238-AM2-C	Core	39.34	28205.08	334.86	480.84	1678.74
RJR238-AM2-D	Core	40.39	11445.03	345.40	1176.09	1239.13
RJR238-AM2-E	Rim	44.61	11408.78	319.88	596.05	1256.42
RJR238-AM3-A	Rim	31.70	11606.71	310.25	296.28	1366.91
RJR238-AM3-B	Rim	27.56	12048.85	361.59	387.94	1361.92
RJR238-AM3-C	Core	31.02	11424.17	334.64	253.05	1352.96
RJR238-AM3-D	Core	33.44	11509.45	316.74	252.97	1356.21
RJR238-AM3-E	Rim	31.71	11876.34	298.92	264.73	1378.39
RJR238-AM3-F	Inter	31.83	11629.25	329.60	379.77	1359.57
RJR238-AM3-G	Rim	31.37	11173.18	302.05	550.34	1363.33
RJR238-AM4-A	Rim	24.79	11458.20	243.59	270.82	1349.45
RJR238-AM4-B	Rim	24.82	11693.62	240.92	285.43	1345.62
RJR238-AM4-C	Inter	24.99	11193.13	277.67	425.23	1383.32
RJR238-AM4-D	Core	29.52	14046.56	375.05	231.59	1434.20
RJR238-AM4-E	Core	34.51	11728.31	336.85	1368.61	1356.63
RJR238-AM4-F	Rim	41.89	10749.67	291.34	391.53	1395.10
RJR238-AM4-G	Rim	41.02	10934.53	271.12	475.46	1386.62
RJR238-AM4-H	Rim	37.97	11208.91	275.43	352.06	1406.83
RJR238-AM5-A	Rim	32.85	11205.51	300.85	315.00	1360.31
RJR238-AM5-B	Rim	35.96	11279.41	314.44	604.32	1364.57
RJR238-AM5-C	Rim	32.18	11364.23	364.23	739.32	1390.04
RJR238-AM5-D	Core	28.70	11840.36	392.74	1083.60	1389.80
RJR238-AM5-E	Core	27.78	11187.81	330.95	113.69	1308.13
RJR238-AM5-F	Rim	32.73	11179.64	311.87	296.68	1282.62
RJR238-AM5-G	Rim	30.05	10815.15	311.81	465.33	1283.17

Table B.2: Continued.

Sample-Grain-Spot	Core/Rim	Sc	Ti	V	Cr	Mn
RJR238-AM5-H	Inter	29.16	10806.62	323.60	526.54	1294.18
RJR238-AM5-I	Rim	31.45	11344.34	335.23	849.73	1341.80
RJR238-AM5-J	Core	27.52	25306.68	325.46	56.19	1590.01
RJR238-AM6-A	Rim	10.41	6788.14	108.13	33.36	1207.98
RJR238-AM6-B	Rim	40.23	10609.50	226.76	425.83	1229.28
RJR238-AM6-C	Inter	39.96	13933.36	282.85	566.54	1322.23
RJR238-AM6-D	Rim	11.67	6737.83	113.08	39.30	1314.66
RJR238-AM6-E	Inter	13.33	7358.99	127.74	42.07	1240.37
RJR238-AM6-F	Core	31.17	17764.77	326.42	137.22	1369.85
RJR238-AM6-G	Core	39.42	21133.29	321.04	378.74	1424.78
RJR238-AM6-H	Rim	10.60	6865.90	118.47	39.13	1275.84
RJR239-AM1-A	Rim	52.51	4630.97	168.75	1609.33	1738.66
RJR239-AM1-B	Rim	52.18	4482.55	179.10	1745.07	1734.12
RJR239-AM1-C	Core	50.26	4584.81	177.33	1627.27	1653.07
RJR239-AM1-D	Rim	36.88	4871.05	173.29	666.38	1664.79
RJR239-AM1-E	Inter	43.06	5272.65	157.10	867.49	1600.80
RJR239-AM1-F	Rim	48.07	4380.78	147.25	1203.06	1583.04
RJR239-AM2-A	Rim	22.10	4036.67	105.67	1624.63	1613.26
RJR239-AM2-B	Core	19.90	4873.59	112.83	803.21	1658.36
RJR239-AM2-C	Core	24.28	4727.74	177.77	1286.60	1673.01
RJR239-AM2-D	Core	29.70	6627.54	226.81	1083.49	1555.48
RJR239-AM2-E	Core	24.57	4635.69	139.47	1867.92	1686.01
RJR239-AM2-F	Rim	14.54	3896.17	86.64	196.84	1758.61
RJR239-AM2-G	Rim	17.08	4211.59	112.63	273.75	1834.09
RJR239-AM2-H	Inter	20.73	4750.10	144.68	1168.79	1740.83
RJR239-AM2-I	Inter	21.55	4812.60	124.80	733.07	1653.99
RJR239-AM2-J	Rim	14.98	4321.02	103.70	511.54	1637.94
RJR239-AM3-A	Rim	8.82	1918.58	56.29	291.09	661.99
RJR239-AM3-B	Rim	11.42	2222.56	72.42	302.84	708.46
RJR239-AM3-C	Core	13.91	2313.87	76.69	1328.73	978.76
RJR239-AM3-E	Rim	3.15	425.80	21.81	64.41	153.60
RJR239-AM3-H	Inter	4.78	2254.16	47.55	209.64	326.66
RJR239-AM3-I	Rim	6.69	1793.05	49.15	279.32	559.00
RJR239-AM3-J	Core	8.58	3878.90	65.15	530.58	600.60
RJR240-AM1-A	Rim	28.37	10304.87	485.43	177.81	1049.29

Table B.2: Continued.

Sample-Grain-Spot	Core/Rim	Sc	Ti	V	Cr	Mn
RJR240-AM1-B	Core	28.61	10259.29	450.44	197.55	979.60
RJR240-AM1-C	Core	35.35	23581.82	487.94	43.19	1344.52
RJR240-AM1-D	Rim	33.42	9474.42	466.31	94.93	984.72
RJR240-AM1-E	Rim	27.99	8402.00	464.53	287.88	946.79
RJR240-AM2-A	Rim	40.39	8280.64	522.04	417.21	1084.96
RJR240-AM2-B	Core	60.86	7784.14	511.42	2059.01	1027.07
RJR240-AM2-C	Core	33.38	9394.87	443.45	939.95	993.52
RJR240-AM2-D	Inter	48.09	9698.37	542.87	994.38	1032.79
RJR240-AM3-A	Rim	10.32	9722.62	303.96	30.94	783.66
RJR240-AM3-B	Rim	14.42	12113.85	400.90	29.72	988.74
RJR240-AM3-C	Core	31.70	37898.98	435.55	50.79	1515.48
RJR240-AM3-D	Core	24.56	19389.48	410.87	24.16	1061.85
RJR240-AM3-E	Inter	24.23	12776.98	417.83	24.20	978.57
RJR240-AM3-F	Rim	22.24	10844.74	433.63	21.52	933.88
RJR240-AM3-G	Core	26.63	24678.10	446.04	13.29	1293.81
RJR240-AM4-A	Rim	37.29	9997.11	478.63	82.82	1010.33
RJR240-AM4-B	Core	40.69	23831.97	477.99	63.08	1279.64
RJR240-AM4-C	Rim	29.78	7844.29	359.25	341.41	731.83
RJR240-AM5-A	Rim	26.55	12836.40	468.12	62.59	944.56
RJR240-AM5-B	Inter	27.92	12731.64	476.83	39.42	949.62
RJR240-AM5-D	Rim	7.54	12108.78	365.08	4.88	984.27
RJR240-AM5-E	Core	31.88	30681.85	462.51	24.92	1307.64
RJR240-AM5-F	Inter	23.78	13981.13	431.48	44.52	1036.12
RJR240-AM5-G	Rim	13.37	13102.43	451.54	15.61	1010.88
RJR240-AM6-A	Rim	23.20	10053.15	419.84	45.98	825.45
RJR240-AM6-B	Rim	25.52	9875.54	403.30	30.21	850.33
RJR240-AM6-C	Rim	11.60	4134.97	129.73	15.12	394.17
RJR240-AM6-D	Rim	21.91	11255.91	436.55	23.55	893.92
RJR240-AM6-E	Inter	19.75	12511.44	446.87	41.25	943.72
RJR240-AM6-F	Rim	26.41	11158.74	458.13	38.68	886.04
RJR240-AM6-G	Core	29.20	19091.39	411.50	17.11	954.50
RJR240-AM6-H	Core	33.78	31549.52	445.50	12.22	1313.07
RJR240-AM6-I	Core	33.42	32765.16	426.97	11.25	1283.51
RJR240-AM7-A	Rim	22.81	11762.70	397.51	11.66	925.57
RJR240-AM7-B	Inter	15.99	12118.98	369.14	18.51	962.09

Table B.2: Continued.

Sample-Grain-Spot	Core/Rim	Sc	Ti	V	Cr	Mn
RJR240-AM7-C	Core	34.85	30361.41	432.44	50.08	1294.94
RJR240-AM7-D	Rim	32.35	11983.15	426.04	47.21	985.95
RJR241-AM2-A	Core	48.99	12365.68	375.98	264.06	1038.63
RJR241-AM2-B	Core	37.19	13169.52	328.15	344.92	1164.63
RJR241-AM2-C	Core	48.05	8900.63	253.10	951.98	993.76
RJR241-AM2-D	Rim	9.65	1738.00	30.46	26.15	1176.30
RJR241-AM2-E	Rim	12.17	5125.34	87.60	86.34	1144.24
RJR241-AM3-A	Rim	64.90	4532.59	249.10	717.39	1022.67
RJR241-AM3-B	Rim	67.54	7918.76	298.89	437.24	969.24
RJR241-AM3-C	Core	66.83	5210.53	253.66	1725.98	1067.62
RJR241-AM3-D	Inter	68.45	4579.94	260.72	1227.29	1039.84
RJR241-AM4-A	Rim	80.58	10787.79	427.72	1825.05	1559.54
RJR241-AM4-B	Core	87.14	5204.43	340.69	1778.68	1314.38
RJR241-AM4-C	Inter	65.97	3199.20	236.81	1650.01	1444.18
RJR241-AM4-D	Core	73.56	4831.91	274.76	1730.22	1254.67
RJR241-AM4-E	Rim	89.18	11064.63	416.31	2053.70	1927.57
RJR242-AM1-A	Rim	34.67	10921.01	280.38	2669.71	1595.64
RJR242-AM1-B	Core	33.12	10989.40	285.98	488.61	1614.32
RJR242-AM1-D	Inter	32.02	10995.65	268.05	713.60	1616.57
RJR242-AM2-A	Rim	32.31	10623.96	271.32	2496.50	1591.29
RJR242-AM2-B	Core	34.13	11034.27	281.14	1417.69	1648.37
RJR242-AM2-C	Rim	35.13	11243.58	282.37	999.59	1595.77
RJR242-AM4-A	Rim	32.38	10807.00	292.48	597.31	1607.53
RJR242-AM4-B	Core	29.16	10741.95	269.33	7352.13	1572.39
RJR242-AM4-C	Rim	32.13	10959.83	293.14	917.85	1639.97
RJR243-AM1-A	Rim	65.95	7296.64	300.92	861.93	1101.53
RJR243-AM1-B	Core	56.94	6563.57	227.71	546.14	1144.18
RJR243-AM1-C	Core	50.69	6678.33	206.97	413.71	1059.50
RJR243-AM1-D	Rim	20.27	3430.03	65.91	28.64	1164.51
RJR243-AM3-A	Rim	8.18	1093.82	19.92	2.68	1299.86
RJR243-AM3-B	Core	9.81	1111.74	13.85	2.62	1402.81
RJR243-AM3-C	Core	22.97	3130.55	74.68	52.82	1367.62
RJR243-AM3-D	Rim	23.09	3130.66	57.73	14.72	1304.18
RJR245-AM1-A	Inter	5.94	7797.07	22.33	bdl	8060.11
RJR245-AM1-B	Rim	5.48	7430.54	21.69	bdl	8307.21

Table B.2: Continued.

Sample-Grain-Spot	Core/Rim	Sc	Ti	V	Cr	Mn
RJR245-AM1-C	Core	5.57	7900.52	22.88	bdl	8408.46
RJR245-AM1-D	Rim	5.32	7628.40	21.78	bdl	7729.72
RJR245-AM1-E	Rim	6.84	7753.92	24.58	bdl	8640.96
RJR245-AM2-A	Core	5.10	8772.20	24.90	bdl	6884.57
RJR245-AM2-B	Rim	6.65	9824.87	27.18	bdl	6319.85
RJR245-AM2-C	Core	13.65	18128.23	46.08	bdl	10752.68
RJR245-AM2-D	Core	5.38	7747.35	29.19	bdl	6843.00
RJR245-AM2-E	Rim	8.74	13573.76	37.77	bdl	8840.28
RJR245-AM2-F	Core	4.10	7938.18	20.00	bdl	6986.21
RJR245-AM4-A	Rim	5.73	6447.47	18.80	bdl	7913.06
RJR245-AM4-B	Rim	7.46	7744.65	23.66	bdl	8806.30
RJR245-AM4-C	Core	5.76	8163.10	24.25	bdl	8310.91
RJR245-AM4-D	Rim	6.01	8298.39	27.66	bdl	8359.75

Table B.2: Continued.

Sample-Grain-Spot	Core/Rim	Fe	Ni	Cu	Rb	Sr	Y
RJR238-AM1-A	Rim	64006.21	228.03	1.74	7.66	300.06	11.02
RJR238-AM1-B	Inter	70414.21	236.43	3.58	7.43	327.92	10.12
RJR238-AM1-C	Core	65209.95	227.35	1.79	8.20	324.68	9.68
RJR238-AM1-D	Rim	61589.62	223.12	1.05	7.47	256.56	12.02
RJR238-AM1-E	Core	62618.04	221.18	1.01	7.62	327.57	11.07
RJR238-AM1-F	Rim	63217.32	231.66	1.20	8.16	275.81	12.69
RJR238-AM1-G	Rim	65149.39	237.25	1.49	8.22	272.19	13.34
RJR238-AM1-H	Core	66229.95	235.25	1.32	7.63	310.01	10.63
RJR238-AM2-A	Inter	59263.50	231.45	1.01	5.34	268.41	11.27
RJR238-AM2-B	Rim	60558.93	233.78	2.78	5.99	257.80	11.68
RJR238-AM2-C	Core	74631.38	307.29	15.81	6.03	301.08	12.93
RJR238-AM2-D	Core	60728.74	213.43	1.32	5.02	290.78	12.89
RJR238-AM2-E	Rim	59356.10	236.40	1.16	5.74	264.70	11.52
RJR238-AM3-A	Rim	66099.34	221.07	1.09	6.71	302.59	11.33
RJR238-AM3-B	Rim	65120.36	219.61	1.04	4.52	316.13	11.63
RJR238-AM3-C	Core	65832.73	225.60	1.35	6.77	293.50	10.62
RJR238-AM3-D	Core	65964.70	217.09	1.36	6.91	305.65	10.80
RJR238-AM3-E	Rim	65986.93	229.49	0.99	6.87	299.15	10.51
RJR238-AM3-F	Inter	64753.75	231.72	4.93	6.37	315.41	11.04
RJR238-AM3-G	Rim	65984.30	230.48	2.05	6.92	290.88	10.75
RJR238-AM4-A	Rim	55545.54	214.52	1.02	6.25	272.14	10.73
RJR238-AM4-B	Rim	56045.00	220.14	0.99	6.30	272.71	10.95
RJR238-AM4-C	Inter	58746.59	226.20	1.09	6.79	302.92	9.23
RJR238-AM4-D	Core	60759.61	221.16	4.17	7.84	328.39	9.30
RJR238-AM4-E	Core	59255.26	202.18	1.09	8.03	325.39	8.65
RJR238-AM4-F	Rim	58222.50	213.62	1.06	6.48	275.01	9.58
RJR238-AM4-G	Rim	58590.05	216.86	1.69	7.11	266.54	10.39
RJR238-AM4-H	Rim	59798.92	211.73	1.13	6.91	288.10	9.68
RJR238-AM5-A	Rim	58025.63	244.14	1.32	6.12	297.30	11.50
RJR238-AM5-B	Rim	58515.71	236.86	1.41	7.10	296.56	11.12
RJR238-AM5-C	Rim	62427.27	248.13	4.74	7.77	319.60	13.19
RJR238-AM5-D	Core	63646.67	238.88	1.19	7.02	341.58	14.89
RJR238-AM5-E	Core	59360.43	210.02	1.77	8.40	328.36	12.76
RJR238-AM5-F	Rim	55967.72	209.82	1.97	6.50	288.51	9.15
RJR238-AM5-G	Rim	56580.34	225.51	1.41	6.46	280.49	12.23

Table B.2: Continued.

Sample-Grain-Spot	Core/Rim	Fe	Ni	Cu	Rb	Sr	Y
RJR238-AM5-H	Inter	57176.72	213.49	1.03	6.79	285.59	11.84
RJR238-AM5-I	Rim	62326.38	234.14	1.56	7.16	301.85	16.64
RJR238-AM5-J	Core	68282.90	217.82	3.71	6.33	321.34	14.35
RJR238-AM6-A	Rim	52212.46	257.29	1.02	3.25	215.09	15.15
RJR238-AM6-B	Rim	53499.87	201.40	0.92	5.01	252.96	14.45
RJR238-AM6-C	Inter	54636.91	202.10	3.16	7.17	257.13	14.63
RJR238-AM6-D	Rim	55658.85	256.84	0.92	12.56	240.59	16.16
RJR238-AM6-E	Inter	56407.82	274.80	3.57	7.60	214.76	16.72
RJR238-AM6-F	Core	58531.72	194.82	7.82	6.85	307.13	21.49
RJR238-AM6-G	Core	60567.22	195.11	4.43	6.41	279.96	18.98
RJR238-AM6-H	Rim	55929.29	268.06	1.17	8.51	210.14	17.38
RJR239-AM1-A	Rim	54379.76	337.05	2.93	2.00	292.54	15.84
RJR239-AM1-B	Rim	54251.37	342.54	1.78	0.50	302.08	16.32
RJR239-AM1-C	Core	53251.83	329.24	1.25	1.30	315.60	18.23
RJR239-AM1-D	Rim	56815.55	355.44	1.76	14.52	320.65	18.33
RJR239-AM1-E	Inter	52374.99	329.84	1.37	1.66	315.33	18.32
RJR239-AM1-F	Rim	50274.38	311.62	1.38	0.37	295.50	16.37
RJR239-AM2-A	Rim	50152.69	319.93	1.34	0.32	310.56	17.94
RJR239-AM2-B	Core	52383.73	332.96	1.36	1.35	326.50	19.76
RJR239-AM2-C	Core	52047.67	328.49	1.44	0.48	314.98	18.77
RJR239-AM2-D	Core	55326.07	316.23	1.28	1.38	371.69	22.86
RJR239-AM2-E	Core	51656.93	337.89	1.68	0.40	308.31	17.78
RJR239-AM2-F	Rim	53618.26	344.89	1.18	0.72	285.59	16.13
RJR239-AM2-G	Rim	54032.15	344.24	1.25	0.26	269.41	15.25
RJR239-AM2-H	Inter	54325.34	334.26	1.26	1.11	307.39	18.06
RJR239-AM2-I	Inter	55421.18	333.91	1.64	0.86	344.05	20.01
RJR239-AM2-J	Rim	48412.76	311.61	1.16	0.33	287.12	14.59
RJR239-AM3-A	Rim	22348.81	126.29	0.48	0.30	124.98	7.00
RJR239-AM3-B	Rim	24422.26	146.82	0.53	0.30	145.81	8.01
RJR239-AM3-C	Core	30990.74	187.85	0.73	0.17	159.75	8.45
RJR239-AM3-E	Rim	4889.74	29.47	0.12	0.05	27.85	1.57
RJR239-AM3-H	Inter	15663.24	71.67	0.90	1.69	73.81	4.06
RJR239-AM3-I	Rim	20406.05	113.43	2.16	1.10	120.33	6.67
RJR239-AM3-J	Core	27207.55	190.39	0.82	62.45	126.95	6.39
RJR240-AM1-A	Rim	61784.09	183.23	1.01	7.19	525.54	12.53

Table B.1: Continued.

Sample-Grain-Spot	Core/Rim	Fe	Ni	Cu	Rb	Sr	Y
RJR240-AM1-B	Core	57155.05	167.31	1.26	6.36	496.06	14.04
RJR240-AM1-C	Core	70434.96	184.84	8.94	7.17	549.79	13.85
RJR240-AM1-D	Rim	60315.40	179.89	4.74	8.58	538.52	13.19
RJR240-AM1-E	Rim	56394.28	161.96	1.69	9.12	527.53	11.55
RJR240-AM2-A	Rim	63065.65	185.89	2.73	9.29	507.79	11.62
RJR240-AM2-B	Core	60185.87	199.78	3.45	6.04	498.31	11.07
RJR240-AM2-C	Core	58676.82	189.11	1.23	5.43	514.91	13.16
RJR240-AM2-D	Inter	63992.09	202.21	1.17	8.24	506.90	10.27
RJR240-AM3-A	Rim	47380.73	118.77	1.37	5.82	474.91	11.21
RJR240-AM3-B	Rim	57718.06	160.74	1.01	6.32	561.13	12.26
RJR240-AM3-C	Core	148366.8	2703.24	5476.3	7.10	558.06	14.50
RJR240-AM3-D	Core	56888.03	147.09	16.84	7.34	562.97	12.51
RJR240-AM3-E	Inter	57252.35	141.71	4.32	6.61	596.90	13.58
RJR240-AM3-F	Rim	56347.79	135.49	2.10	9.34	535.97	10.59
RJR240-AM3-G	Core	66606.08	162.61	28.95	6.60	568.25	12.01
RJR240-AM4-A	Rim	63920.90	204.39	1.61	13.75	595.03	14.78
RJR240-AM4-B	Core	66383.89	208.28	3.63	6.37	576.84	14.99
RJR240-AM4-C	Rim	45911.52	150.23	1.16	5.00	407.20	12.10
RJR240-AM5-A	Rim	55739.03	133.32	1.43	6.57	523.02	14.44
RJR240-AM5-B	Inter	58787.76	132.93	0.98	7.62	534.55	12.87
RJR240-AM5-D	Rim	59578.11	149.64	0.75	6.29	494.69	14.70
RJR240-AM5-E	Core	70051.68	142.61	5.50	7.11	585.26	14.89
RJR240-AM5-F	Inter	63135.59	144.95	1.16	5.14	510.85	19.71
RJR240-AM5-G	Rim	62338.05	149.68	1.11	5.05	521.16	12.97
RJR240-AM6-A	Rim	38507.24	121.01	0.85	5.97	442.51	10.84
RJR240-AM6-B	Rim	40887.23	128.11	1.33	5.49	460.82	12.20
RJR240-AM6-C	Rim	15886.21	62.18	14.10	33.01	185.87	5.27
RJR240-AM6-D	Rim	40946.95	125.12	2.51	6.15	439.79	12.82
RJR240-AM6-E	Inter	45458.34	131.47	1.74	6.02	472.15	11.77
RJR240-AM6-F	Rim	42758.24	129.78	1.50	7.69	466.60	10.93
RJR240-AM6-G	Core	41180.47	129.75	4.61	6.37	501.51	17.00
RJR240-AM6-H	Core	51659.86	138.39	9.97	6.13	531.87	12.20
RJR240-AM6-I	Core	49556.04	127.71	8.50	5.62	530.82	12.89
RJR240-AM7-A	Rim	60120.58	161.88	4.00	6.14	533.23	12.04
RJR240-AM7-B	Inter	59063.04	153.45	1.05	5.35	525.84	11.68

Table B.2: Continued.

Sample-Grain-Spot	Core/Rim	Fe	Ni	Cu	Rb	Sr	Y
RJR240-AM7-C	Core	69392.61	157.77	6.61	5.63	531.15	13.38
RJR240-AM7-D	Rim	58622.82	170.94	2.40	6.47	577.99	12.60
RJR241-AM2-A	Core	46436.86	310.05	101.1	5.14	83.46	31.42
RJR241-AM2-B	Core	51465.98	247.13	5.05	6.60	87.50	32.27
RJR241-AM2-C	Core	40563.01	217.44	3.02	5.89	65.80	22.20
RJR241-AM2-D	Rim	43824.40	238.14	1.34	3.41	32.14	5.76
RJR241-AM2-E	Rim	47718.14	230.74	1.71	6.97	40.89	7.20
RJR241-AM3-A	Rim	24914.00	100.20	1.18	1.23	33.21	6.95
RJR241-AM3-B	Rim	39724.60	193.01	1.44	3.48	45.83	15.55
RJR241-AM3-C	Core	26151.17	103.18	1.11	0.85	33.53	8.31
RJR241-AM3-D	Inter	25205.22	104.86	1.21	1.59	36.40	9.55
RJR241-AM4-A	Rim	60154.88	271.41	2.26	7.98	116.89	23.18
RJR241-AM4-B	Core	32061.00	119.53	1.48	1.13	40.06	10.06
RJR241-AM4-C	Inter	32983.29	118.31	1.42	1.39	38.04	5.53
RJR241-AM4-D	Core	29779.88	118.85	13.40	1.14	38.17	7.57
RJR241-AM4-E	Rim	82125.55	415.79	19.86	10.90	79.84	23.76
RJR242-AM1-A	Rim	44695.51	264.21	2.12	13.20	229.20	14.87
RJR242-AM1-B	Core	46919.15	274.48	5.85	11.32	241.32	13.90
RJR242-AM1-D	Inter	45697.47	269.76	1.84	8.94	234.76	13.88
RJR242-AM2-A	Rim	44913.82	266.69	1.74	7.28	235.35	12.87
RJR242-AM2-B	Core	47968.26	280.96	1.65	10.38	238.30	13.94
RJR242-AM2-C	Rim	46241.24	270.87	1.90	9.37	236.86	13.46
RJR242-AM4-A	Rim	46558.93	275.32	2.82	11.35	251.14	14.89
RJR242-AM4-B	Core	46050.15	272.91	1.78	10.98	262.50	14.05
RJR242-AM4-C	Rim	47157.85	283.63	6.06	13.52	234.99	14.26
RJR243-AM1-A	Rim	37015.53	125.95	1.89	5.76	72.31	17.64
RJR243-AM1-B	Core	40132.37	138.40	1.56	5.96	59.82	15.46
RJR243-AM1-C	Core	39698.01	149.61	1.77	8.41	70.80	14.56
RJR243-AM1-D	Rim	42168.40	165.42	2.10	12.85	85.11	16.69
RJR243-AM3-A	Rim	49042.35	136.06	1.36	10.96	42.38	11.93
RJR243-AM3-B	Core	47155.41	125.83	1.01	5.09	35.73	11.49
RJR243-AM3-C	Core	46445.37	137.12	1.16	4.10	45.46	14.83
RJR243-AM3-D	Rim	45729.45	133.81	1.12	4.46	47.70	16.87
RJR245-AM1-A	Inter	104614.4	2.87	3.69	19.17	82.63	266.65
RJR245-AM1-B	Rim	105279.1	2.92	4.86	17.58	84.36	258.61

Table B.2: Continued.

Sample-Grain-Spot	Core/Rim	Fe	Ni	Cu	Rb	Sr	Y
RJR245-AM1-C	Core	113036.01	2.92	2.41	19.14	89.44	248.06
RJR245-AM1-D	Rim	104628.59	2.55	0.89	17.96	85.37	266.67
RJR245-AM1-E	Rim	104280.84	2.38	0.63	16.91	84.34	272.58
RJR245-AM2-A	Core	103065.32	3.15	14.58	18.73	93.78	272.38
RJR245-AM2-B	Rim	111761.48	12.77	288.56	51.82	130.4	302.85
RJR245-AM2-C	Core	295237.86	15.25	262.28	339.08	145.8	507.78
RJR245-AM2-D	Core	109011.04	6.50	99.76	33.39	97.65	239.27
RJR245-AM2-E	Rim	172144.04	25.31	633.93	99.10	119.7	455.80
RJR245-AM2-F	Core	105855.75	5.70	69.07	26.34	91.97	269.86
RJR245-AM4-A	Rim	107042.55	2.87	16.66	13.56	83.77	269.83
RJR245-AM4-B	Rim	105227.91	2.96	24.79	18.08	85.56	263.11
RJR245-AM4-C	Core	109156.43	2.67	2.99	18.16	89.38	279.99
RJR245-AM4-D	Rim	110798.35	6.32	148.92	22.54	90.63	274.86

Table B.2: Continued.

Sample-Grain-Spot	Core/Rim	Zr	Nb	Mo	Ba	La	Ce
RJR238-AM1-A	Rim	28.56	23.30	0.20	198.36	7.70	21.45
RJR238-AM1-B	Inter	32.09	22.93	0.28	297.83	8.55	22.01
RJR238-AM1-C	Core	30.64	15.95	0.20	278.16	7.84	21.19
RJR238-AM1-D	Rim	28.28	29.26	0.16	157.38	8.56	23.92
RJR238-AM1-E	Core	52.23	21.81	bdl	208.78	7.75	21.14
RJR238-AM1-F	Rim	28.26	25.85	0.14	173.07	8.13	23.53
RJR238-AM1-G	Rim	28.86	30.44	0.20	145.76	8.58	24.83
RJR238-AM1-H	Core	30.38	19.70	0.21	260.39	8.07	21.96
RJR238-AM2-A	Inter	33.65	27.26	0.13	111.26	8.75	23.51
RJR238-AM2-B	Rim	27.30	24.08	0.24	172.87	8.95	24.48
RJR238-AM2-C	Core	40.55	44.01	0.14	279.38	11.43	28.07
RJR238-AM2-D	Core	33.37	20.15	0.21	196.20	10.22	26.19
RJR238-AM2-E	Rim	28.67	20.11	0.12	223.42	8.61	23.48
RJR238-AM3-A	Rim	28.25	26.59	0.27	129.90	7.92	21.98
RJR238-AM3-B	Rim	50.07	31.06	bdl	102.75	8.32	23.45
RJR238-AM3-C	Core	27.25	21.33	0.17	184.13	8.03	21.51
RJR238-AM3-D	Core	28.83	26.88	bdl	150.93	8.06	21.80
RJR238-AM3-E	Rim	30.94	26.09	0.15	163.14	7.94	21.14
RJR238-AM3-F	Inter	30.64	25.34	0.24	237.12	8.64	22.23
RJR238-AM3-G	Rim	27.05	28.70	0.25	161.75	7.79	21.01
RJR238-AM4-A	Rim	33.34	29.86	0.25	106.13	7.60	20.68
RJR238-AM4-B	Rim	29.96	29.87	0.22	79.44	7.31	19.88
RJR238-AM4-C	Inter	35.86	23.00	bdl	159.38	7.61	18.99
RJR238-AM4-D	Core	33.68	15.12	bdl	314.64	9.91	23.66
RJR238-AM4-E	Core	30.88	13.67	0.16	229.50	8.34	21.02
RJR238-AM4-F	Rim	28.12	21.45	0.28	149.22	7.78	20.22
RJR238-AM4-G	Rim	28.66	25.22	0.15	148.26	8.50	22.19
RJR238-AM4-H	Rim	30.34	24.09	bdl	79.68	7.38	18.71
RJR238-AM5-A	Rim	31.16	29.23	0.19	146.11	8.66	24.11
RJR238-AM5-B	Rim	28.44	27.95	0.24	146.16	8.24	23.85
RJR238-AM5-C	Rim	31.30	25.74	0.24	219.34	10.01	27.97
RJR238-AM5-D	Core	36.87	24.53	0.26	148.79	9.76	30.04
RJR238-AM5-E	Core	34.50	24.14	0.17	300.51	8.19	23.49
RJR238-AM5-F	Rim	29.94	16.59	0.17	177.64	7.04	19.49
RJR238-AM5-G	Rim	27.40	26.19	0.12	208.49	7.60	22.63

Table B.2: Continued.

Sample-Grain-Spot	Core/Rim	Zr	Nb	Mo	Ba	La	Ce
RJR238-AM5-H	Inter	30.47	23.68	0.21	166.30	7.95	23.29
RJR238-AM5-I	Rim	31.75	32.84	0.19	234.27	9.26	29.55
RJR238-AM5-J	Core	31.02	45.65	0.21	319.14	8.27	23.38
RJR238-AM6-A	Rim	29.14	26.53	0.23	40.73	8.64	27.02
RJR238-AM6-B	Rim	30.08	35.31	0.19	82.26	9.32	27.66
RJR238-AM6-C	Inter	26.63	42.15	0.23	176.90	9.21	27.91
RJR238-AM6-D	Rim	29.48	29.47	0.17	150.94	9.05	29.80
RJR238-AM6-E	Inter	30.08	35.28	0.19	140.57	9.31	30.24
RJR238-AM6-F	Core	67.28	61.82	bdl	331.16	10.24	34.65
RJR238-AM6-G	Core	39.59	54.54	0.19	225.03	10.56	31.20
RJR238-AM6-H	Rim	30.33	34.60	bdl	106.36	8.83	29.96
RJR239-AM1-A	Rim	43.49	16.51	0.22	17.76	15.05	45.29
RJR239-AM1-B	Rim	41.05	16.42	0.20	6.41	15.41	47.06
RJR239-AM1-C	Core	46.52	19.77	0.26	9.94	17.34	52.89
RJR239-AM1-D	Rim	55.08	21.91	0.30	59.39	17.33	54.38
RJR239-AM1-E	Inter	86.78	29.11	0.19	19.13	17.91	52.75
RJR239-AM1-F	Rim	42.53	17.57	0.18	5.95	15.78	46.78
RJR239-AM2-A	Rim	58.05	20.12	0.24	4.65	16.33	49.02
RJR239-AM2-B	Core	330.70	59.88	0.23	21.73	18.13	56.73
RJR239-AM2-C	Core	69.08	23.04	0.26	5.42	17.27	53.20
RJR239-AM2-D	Core	102.28	39.99	0.24	60.23	20.44	58.84
RJR239-AM2-E	Core	64.32	22.77	0.29	5.00	15.77	47.06
RJR239-AM2-F	Rim	300.00	39.73	0.35	5.46	15.08	46.29
RJR239-AM2-G	Rim	86.15	22.27	0.24	3.51	13.95	44.19
RJR239-AM2-H	Inter	67.69	28.47	0.22	13.26	16.14	49.21
RJR239-AM2-I	Inter	214.39	38.88	0.31	10.75	19.32	59.10
RJR239-AM2-J	Rim	97.26	28.15	0.28	4.95	14.10	44.36
RJR239-AM3-A	Rim	19.59	7.68	0.10	2.89	7.41	22.27
RJR239-AM3-B	Rim	36.17	9.61	0.07	3.77	8.20	24.56
RJR239-AM3-C	Core	24.39	9.37	0.13	2.25	8.81	25.78
RJR239-AM3-E	Rim	4.43	1.23	0.02	0.59	1.61	4.77
RJR239-AM3-H	Inter	12.35	9.26	0.14	46.32	4.65	13.12
RJR239-AM3-I	Rim	22.83	10.76	0.11	24.28	7.70	22.48
RJR239-AM3-J	Core	18.08	13.57	0.12	180.15	6.86	19.81
RJR240-AM1-A	Rim	65.42	22.13	0.20	149.23	10.42	30.08

Table B.2: Continued.

Sample-Grain-Spot	Core/Rim	Zr	Nb	Mo	Ba	La	Ce
RJR240-AM1-B	Core	77.55	23.57	0.23	260.27	12.38	35.73
RJR240-AM1-C	Core	72.57	31.29	bdl	473.07	8.58	23.68
RJR240-AM1-D	Rim	61.52	19.35	0.23	372.29	9.38	26.44
RJR240-AM1-E	Rim	56.21	17.59	0.20	223.11	8.71	23.76
RJR240-AM2-A	Rim	58.04	18.82	bdl	356.86	9.73	26.88
RJR240-AM2-B	Core	76.69	14.64	bdl	337.54	7.72	21.04
RJR240-AM2-C	Core	102.41	23.87	bdl	180.51	9.30	26.08
RJR240-AM2-D	Inter	65.49	13.73	bdl	252.26	8.37	23.18
RJR240-AM3-A	Rim	71.61	17.60	bdl	182.90	5.99	18.46
RJR240-AM3-B	Rim	82.13	24.75	bdl	226.34	8.28	25.03
RJR240-AM3-C	Core	94.47	42.15	5.08	434.41	8.39	24.03
RJR240-AM3-D	Core	82.65	26.70	bdl	462.47	7.20	21.30
RJR240-AM3-E	Inter	103.44	27.45	bdl	207.18	8.60	24.64
RJR240-AM3-F	Rim	108.85	25.15	0.18	316.81	7.14	20.22
RJR240-AM3-G	Core	90.40	31.68	0.32	424.23	7.22	18.98
RJR240-AM4-A	Rim	119.77	30.20	0.19	188.92	13.04	35.38
RJR240-AM4-B	Core	102.29	28.51	bdl	516.08	10.57	25.61
RJR240-AM4-C	Rim	42.70	12.87	bdl	189.26	7.76	20.84
RJR240-AM5-A	Rim	107.95	26.63	bdl	220.51	10.43	31.92
RJR240-AM5-B	Inter	63.51	19.50	bdl	244.38	8.69	25.13
RJR240-AM5-D	Rim	66.65	25.36	0.28	245.68	9.14	27.80
RJR240-AM5-E	Core	93.85	37.99	bdl	391.93	9.05	25.79
RJR240-AM5-F	Inter	168.77	49.32	bdl	104.52	11.75	36.03
RJR240-AM5-G	Rim	65.69	20.50	bdl	184.61	11.16	33.38
RJR240-AM6-A	Rim	55.49	18.42	bdl	216.10	7.14	21.44
RJR240-AM6-B	Rim	57.59	18.15	bdl	346.41	7.11	21.43
RJR240-AM6-C	Rim	96.71	8.44	bdl	311.89	4.70	10.42
RJR240-AM6-D	Rim	101.21	26.17	bdl	199.98	8.01	28.36
RJR240-AM6-E	Inter	86.37	24.78	bdl	185.41	7.45	21.96
RJR240-AM6-F	Rim	71.21	21.77	0.30	214.00	7.46	21.03
RJR240-AM6-G	Core	83.25	30.94	bdl	374.68	11.67	36.22
RJR240-AM6-H	Core	78.48	32.00	0.34	439.76	7.36	22.24
RJR240-AM6-I	Core	84.42	33.37	0.20	428.97	6.94	22.37
RJR240-AM7-A	Rim	50.98	14.92	bdl	200.04	7.65	20.37
RJR240-AM7-B	Inter	62.41	15.96	bdl	223.21	6.57	18.57

Table B.2: Continued.

Sample-Grain-Spot	Core/Rim	Zr	Nb	Mo	Ba	La	Ce
RJR240-AM7-C	Core	84.29	32.69	bdl	399.19	7.85	19.70
RJR240-AM7-D	Rim	62.88	18.71	bdl	414.21	9.33	25.81
RJR241-AM2-A	Core	25.34	33.48	0.98	70.77	8.12	29.51
RJR241-AM2-B	Core	78.13	38.12	0.31	180.13	7.72	33.69
RJR241-AM2-C	Core	119.24	22.22	0.72	117.61	7.98	28.10
RJR241-AM2-D	Rim	58.33	8.09	0.14	23.36	5.73	17.56
RJR241-AM2-E	Rim	53.37	12.23	0.19	67.04	4.74	17.64
RJR241-AM3-A	Rim	25.12	0.25	0.13	20.28	1.69	5.33
RJR241-AM3-B	Rim	31.10	1.67	bdl	41.21	2.98	10.63
RJR241-AM3-C	Core	19.32	0.12	0.17	10.65	1.42	4.38
RJR241-AM3-D	Inter	43.89	0.73	0.13	11.98	1.94	6.01
RJR241-AM4-A	Rim	48.27	0.88	0.48	98.07	4.89	16.42
RJR241-AM4-B	Core	26.36	0.13	0.19	14.99	2.11	6.23
RJR241-AM4-C	Inter	21.28	0.28	0.22	13.10	2.22	6.22
RJR241-AM4-D	Core	24.80	0.31	0.14	14.83	2.12	6.35
RJR241-AM4-E	Rim	51.69	1.63	0.33	77.99	7.28	25.56
RJR242-AM1-A	Rim	31.41	39.51	0.21	272.54	13.26	37.61
RJR242-AM1-B	Core	36.00	41.58	0.28	501.11	13.78	38.15
RJR242-AM1-D	Inter	33.23	40.83	0.21	152.54	12.24	35.86
RJR242-AM2-A	Rim	36.85	43.16	0.28	141.41	13.75	37.82
RJR242-AM2-B	Core	33.82	41.74	0.28	210.57	13.39	38.65
RJR242-AM2-C	Rim	33.08	41.56	0.24	383.51	13.59	39.09
RJR242-AM4-A	Rim	34.20	43.85	0.22	462.48	13.34	39.09
RJR242-AM4-B	Core	32.03	40.19	0.21	445.86	13.09	39.05
RJR242-AM4-C	Rim	35.48	42.66	0.25	445.73	13.13	39.49
RJR243-AM1-A	Rim	63.45	12.98	0.19	147.19	6.74	21.90
RJR243-AM1-B	Core	42.29	4.32	0.78	62.66	5.94	19.37
RJR243-AM1-C	Core	73.06	4.45	0.44	84.22	6.14	20.88
RJR243-AM1-D	Rim	25.18	3.92	0.16	91.87	5.62	16.35
RJR243-AM3-A	Rim	28.40	2.05	0.21	66.42	6.14	23.33
RJR243-AM3-B	Core	30.67	2.68	0.21	25.30	6.17	23.91
RJR243-AM3-C	Core	30.85	4.73	0.23	27.75	5.74	22.34
RJR243-AM3-D	Rim	34.06	4.94	0.31	51.28	5.90	23.38
RJR245-AM1-A	Inter	47.02	1091.67	1.20	187.29	12.50	59.75
RJR245-AM1-B	Rim	42.73	1005.67	1.09	187.60	12.89	59.85

Table B.2: Continued.

Sample-Grain-Spot	Core/Rim	Zr	Nb	Mo	Ba	La	Ce
RJR245-AM1-C	Core	50.73	1164.39	1.25	177.22	13.04	61.59
RJR245-AM1-D	Rim	46.92	1009.58	1.06	187.35	12.96	59.11
RJR245-AM1-E	Rim	43.28	1070.66	1.30	195.76	13.08	60.88
RJR245-AM2-A	Core	47.44	1111.06	1.05	238.45	15.59	65.90
RJR245-AM2-B	Rim	52.13	1277.88	0.94	189.28	31.64	112.45
RJR245-AM2-C	Core	98.01	2684.39	1.92	445.15	44.30	170.93
RJR245-AM2-D	Core	41.69	900.91	0.97	171.83	16.60	67.85
RJR245-AM2-E	Rim	82.41	2186.34	1.40	271.99	67.90	239.58
RJR245-AM2-F	Core	47.57	1113.03	0.97	213.86	17.53	67.74
RJR245-AM4-A	Rim	33.34	833.29	1.18	113.84	9.85	51.69
RJR245-AM4-B	Rim	41.92	1063.45	1.20	191.99	13.66	60.54
RJR245-AM4-C	Core	46.18	1043.78	1.13	189.13	12.90	58.77
RJR245-AM4-D	Rim	46.22	1102.06	1.49	196.31	18.33	68.50

Table B.2: Continued.

Sample-Grain-Spot	Core/Rim	Pr	Nd	Sm	Eu	Gd
RJR238-AM1-A	Rim	2.95	12.79	3.02	1.05	3.26
RJR238-AM1-B	Inter	2.74	12.16	2.84	0.96	2.99
RJR238-AM1-C	Core	2.73	11.71	2.77	0.94	2.64
RJR238-AM1-D	Rim	3.38	15.60	3.70	1.15	3.75
RJR238-AM1-E	Core	2.77	12.59	3.13	0.96	3.60
RJR238-AM1-F	Rim	3.26	14.93	3.75	1.10	3.72
RJR238-AM1-G	Rim	3.49	16.04	3.68	1.15	4.31
RJR238-AM1-H	Core	2.98	13.06	3.19	1.07	3.12
RJR238-AM2-A	Inter	3.31	14.93	3.50	1.12	3.74
RJR238-AM2-B	Rim	3.41	14.95	3.78	1.19	3.55
RJR238-AM2-C	Core	3.64	16.49	3.87	1.25	4.33
RJR238-AM2-D	Core	3.53	16.30	4.01	1.29	4.15
RJR238-AM2-E	Rim	3.19	15.24	3.50	1.16	3.58
RJR238-AM3-A	Rim	3.06	14.83	3.43	1.03	3.70
RJR238-AM3-B	Rim	3.45	16.76	4.01	1.01	4.06
RJR238-AM3-C	Core	3.03	13.86	3.12	1.12	3.16
RJR238-AM3-D	Core	3.04	13.51	3.58	1.00	3.19
RJR238-AM3-E	Rim	2.92	13.55	3.21	1.06	3.31
RJR238-AM3-F	Inter	3.08	14.44	3.54	1.05	3.46
RJR238-AM3-G	Rim	3.02	13.97	3.50	1.08	3.46
RJR238-AM4-A	Rim	2.80	13.60	3.31	0.93	3.39
RJR238-AM4-B	Rim	2.71	12.86	3.29	0.92	3.12
RJR238-AM4-C	Inter	2.36	10.75	2.53	0.81	2.87
RJR238-AM4-D	Core	2.79	11.90	2.68	1.00	2.85
RJR238-AM4-E	Core	2.60	11.22	2.73	1.00	2.69
RJR238-AM4-F	Rim	2.72	12.37	2.84	0.92	2.94
RJR238-AM4-G	Rim	2.91	13.44	3.18	1.01	3.16
RJR238-AM4-H	Rim	2.53	11.53	2.80	0.85	2.88
RJR238-AM5-A	Rim	3.28	15.20	3.75	1.10	3.31
RJR238-AM5-B	Rim	3.30	15.05	3.72	1.12	3.38
RJR238-AM5-C	Rim	3.84	17.10	4.02	1.29	4.09
RJR238-AM5-D	Core	4.18	19.05	4.80	1.57	4.70
RJR238-AM5-E	Core	3.26	14.92	3.82	1.18	4.14
RJR238-AM5-F	Rim	2.63	11.88	2.85	0.98	2.64
RJR238-AM5-G	Rim	3.27	15.41	3.53	1.09	3.57

Table B.2: Continued.

Sample-Grain-Spot	Core/Rim	Pr	Nd	Sm	Eu	Gd
RJR238-AM5-H	Inter	3.31	15.05	3.51	1.12	3.60
RJR238-AM5-I	Rim	4.38	20.45	5.09	1.69	5.12
RJR238-AM5-J	Core	3.37	16.28	4.24	1.24	4.36
RJR238-AM6-A	Rim	3.89	18.29	4.51	1.59	4.37
RJR238-AM6-B	Rim	4.02	18.97	4.67	1.38	4.57
RJR238-AM6-C	Inter	4.12	18.93	4.70	1.40	5.01
RJR238-AM6-D	Rim	4.36	21.20	4.85	1.67	4.60
RJR238-AM6-E	Inter	4.43	21.60	5.21	1.62	5.08
RJR238-AM6-F	Core	5.69	29.03	7.52	2.19	7.37
RJR238-AM6-G	Core	4.69	23.58	6.48	1.69	6.04
RJR238-AM6-H	Rim	4.37	21.72	5.15	1.63	4.75
RJR239-AM1-A	Rim	6.17	27.10	6.20	2.12	5.43
RJR239-AM1-B	Rim	6.47	28.77	6.46	2.14	5.22
RJR239-AM1-C	Core	7.38	32.60	7.47	2.44	6.20
RJR239-AM1-D	Rim	7.52	33.22	7.33	2.53	6.68
RJR239-AM1-E	Inter	7.43	32.67	7.26	2.48	5.99
RJR239-AM1-F	Rim	6.53	28.76	6.46	2.10	5.61
RJR239-AM2-A	Rim	6.96	31.57	7.19	2.28	6.18
RJR239-AM2-B	Core	7.91	34.63	7.32	2.39	5.92
RJR239-AM2-C	Core	7.39	33.63	7.38	2.53	6.27
RJR239-AM2-D	Core	8.37	39.61	8.97	2.90	8.23
RJR239-AM2-E	Core	6.52	29.78	6.55	2.26	5.75
RJR239-AM2-F	Rim	6.42	27.66	5.78	2.10	4.91
RJR239-AM2-G	Rim	6.21	28.00	5.89	2.05	5.07
RJR239-AM2-H	Inter	6.97	31.39	6.83	2.39	6.37
RJR239-AM2-I	Inter	8.13	35.27	7.87	2.58	6.84
RJR239-AM2-J	Rim	6.21	28.52	6.48	2.01	5.44
RJR239-AM3-A	Rim	3.01	13.27	3.01	1.04	2.52
RJR239-AM3-B	Rim	3.32	14.64	3.19	1.04	2.77
RJR239-AM3-C	Core	3.34	14.20	3.26	1.16	3.01
RJR239-AM3-E	Rim	0.63	2.75	0.63	0.22	0.56
RJR239-AM3-H	Inter	1.78	7.74	1.72	0.56	1.52
RJR239-AM3-I	Rim	2.91	12.70	2.67	0.93	2.39
RJR239-AM3-J	Core	2.64	11.46	2.54	0.83	2.14
RJR240-AM1-A	Rim	4.42	20.43	4.95	1.52	4.18

Table B.2: Continued.

Sample-Grain-Spot	Core/Rim	Pr	Nd	Sm	Eu	Gd
RJR240-AM1-B	Core	4.87	23.87	5.36	1.66	5.18
RJR240-AM1-C	Core	3.60	18.25	4.65	1.42	4.71
RJR240-AM1-D	Rim	3.84	18.48	4.57	1.59	4.42
RJR240-AM1-E	Rim	3.35	15.44	4.20	1.34	3.85
RJR240-AM2-A	Rim	3.91	17.69	4.38	1.46	4.42
RJR240-AM2-B	Core	2.97	13.75	3.69	1.12	3.50
RJR240-AM2-C	Core	4.00	20.49	4.99	1.27	5.20
RJR240-AM2-D	Inter	3.28	14.33	3.40	1.23	3.36
RJR240-AM3-A	Rim	3.01	15.57	4.13	1.22	3.82
RJR240-AM3-B	Rim	3.95	19.48	4.96	1.27	4.46
RJR240-AM3-C	Core	3.78	19.53	6.28	1.74	5.62
RJR240-AM3-D	Core	3.51	19.30	4.84	1.46	4.69
RJR240-AM3-E	Inter	3.84	19.45	4.75	1.42	4.74
RJR240-AM3-F	Rim	2.98	15.23	3.60	1.10	3.37
RJR240-AM3-G	Core	2.92	15.09	3.93	1.28	4.09
RJR240-AM4-A	Rim	5.30	25.22	5.50	1.69	5.32
RJR240-AM4-B	Core	3.74	19.07	5.25	1.59	5.22
RJR240-AM4-C	Rim	3.10	14.89	4.14	1.30	4.03
RJR240-AM5-A	Rim	5.06	23.48	5.93	1.95	5.35
RJR240-AM5-B	Inter	3.72	17.76	4.31	1.41	4.00
RJR240-AM5-D	Rim	4.45	20.72	5.68	1.63	5.27
RJR240-AM5-E	Core	3.88	20.87	5.88	1.76	6.28
RJR240-AM5-F	Inter	5.58	28.32	7.43	2.30	7.28
RJR240-AM5-G	Rim	5.03	24.13	5.42	1.51	4.95
RJR240-AM6-A	Rim	3.32	16.66	4.23	1.34	3.90
RJR240-AM6-B	Rim	3.40	16.93	4.51	1.44	4.46
RJR240-AM6-C	Rim	1.52	6.72	1.82	0.56	1.35
RJR240-AM6-D	Rim	4.52	22.11	5.71	1.54	4.91
RJR240-AM6-E	Inter	3.70	18.92	5.46	1.47	5.52
RJR240-AM6-F	Rim	3.22	15.14	4.07	1.34	3.84
RJR240-AM6-G	Core	5.54	25.99	6.59	2.31	5.43
RJR240-AM6-H	Core	3.64	19.96	5.71	1.72	4.97
RJR240-AM6-I	Core	3.95	21.90	6.10	1.84	5.54
RJR240-AM7-A	Rim	3.11	15.16	3.71	1.41	4.32
RJR240-AM7-B	Inter	2.90	14.71	4.31	1.35	3.99

Table B.2: Continued.

Sample-Grain-Spot	Core/Rim	Pr	Nd	Sm	Eu	Gd
RJR240-AM7-C	Core	3.13	17.52	5.15	1.56	4.84
RJR240-AM7-D	Rim	3.98	19.60	4.85	1.50	5.04
RJR241-AM2-A	Core	4.90	25.97	7.84	2.19	8.47
RJR241-AM2-B	Core	6.16	33.31	9.48	2.55	10.09
RJR241-AM2-C	Core	4.31	21.51	6.19	1.63	6.22
RJR241-AM2-D	Rim	2.27	9.18	1.90	1.21	1.57
RJR241-AM2-E	Rim	2.49	10.91	2.29	1.49	1.95
RJR241-AM3-A	Rim	0.90	4.86	1.57	0.53	1.77
RJR241-AM3-B	Rim	1.78	10.25	3.36	1.11	4.01
RJR241-AM3-C	Core	0.74	4.31	1.58	0.52	2.25
RJR241-AM3-D	Inter	1.00	5.64	1.85	0.62	2.33
RJR241-AM4-A	Rim	2.66	14.04	4.90	2.00	5.96
RJR241-AM4-B	Core	0.96	5.42	2.06	0.67	2.60
RJR241-AM4-C	Inter	0.90	4.69	1.38	0.54	1.44
RJR241-AM4-D	Core	0.95	5.21	1.57	0.55	1.98
RJR241-AM4-E	Rim	3.31	17.83	5.65	2.40	6.15
RJR242-AM1-A	Rim	4.82	20.00	3.93	1.37	3.53
RJR242-AM1-B	Core	4.79	19.73	3.90	1.35	3.45
RJR242-AM1-D	Inter	4.61	19.03	3.82	1.28	3.40
RJR242-AM2-A	Rim	4.71	19.31	3.84	1.22	3.24
RJR242-AM2-B	Core	4.82	19.33	3.64	1.32	3.58
RJR242-AM2-C	Rim	4.92	19.89	3.83	1.38	3.36
RJR242-AM4-A	Rim	5.07	21.43	4.01	1.36	3.91
RJR242-AM4-B	Core	5.07	20.90	4.27	1.28	3.84
RJR242-AM4-C	Rim	5.06	20.18	4.18	1.34	3.63
RJR243-AM1-A	Rim	3.41	16.52	4.46	1.52	5.09
RJR243-AM1-B	Core	3.04	14.33	3.72	1.34	3.90
RJR243-AM1-C	Core	3.23	15.04	4.03	1.48	4.16
RJR243-AM1-D	Rim	2.47	12.49	3.46	1.63	3.59
RJR243-AM3-A	Rim	3.48	14.40	3.08	1.94	2.37
RJR243-AM3-B	Core	3.71	16.10	3.24	1.68	2.77
RJR243-AM3-C	Core	3.51	16.12	3.98	1.47	3.65
RJR243-AM3-D	Rim	3.75	17.70	4.14	1.63	4.08
RJR245-AM1-A	Inter	12.80	77.42	32.92	10.66	39.23
RJR245-AM1-B	Rim	12.55	74.78	31.28	10.27	37.34

Table B.2: Continued.

Sample-Grain-Spot	Core/Rim	Pr	Nd	Sm	Eu	Gd
RJR245-AM1-C	Core	12.82	78.30	32.99	10.77	38.47
RJR245-AM1-D	Rim	12.36	73.51	31.67	10.43	38.01
RJR245-AM1-E	Rim	12.92	78.51	32.56	10.38	39.46
RJR245-AM2-A	Core	12.66	71.45	31.22	10.10	39.67
RJR245-AM2-B	Rim	19.84	103.50	39.74	12.47	47.88
RJR245-AM2-C	Core	30.88	158.39	65.21	24.24	80.77
RJR245-AM2-D	Core	12.97	71.84	29.04	11.37	34.49
RJR245-AM2-E	Rim	39.17	198.92	79.53	23.75	91.05
RJR245-AM2-F	Core	13.22	74.10	30.70	10.12	38.60
RJR245-AM4-A	Rim	12.39	79.19	35.19	11.98	40.48
RJR245-AM4-B	Rim	12.74	75.85	31.94	10.47	37.96
RJR245-AM4-C	Core	12.29	72.69	30.93	10.19	37.79
RJR245-AM4-D	Rim	13.79	79.47	32.13	10.44	38.46

Table B.2: Continued.

Sample-Grain-Spot	Core/Rim	Tb	Dy	Ho	Er	Tm
RJR238-AM1-A	Rim	0.40	2.61	0.42	1.20	0.13
RJR238-AM1-B	Inter	0.34	2.01	0.38	1.09	0.13
RJR238-AM1-C	Core	0.38	2.16	0.37	0.97	0.11
RJR238-AM1-D	Rim	0.48	2.54	0.50	1.34	0.16
RJR238-AM1-E	Core	0.44	2.47	0.44	1.09	0.16
RJR238-AM1-F	Rim	0.48	2.76	0.49	1.22	0.18
RJR238-AM1-G	Rim	0.53	2.89	0.50	1.32	0.17
RJR238-AM1-H	Core	0.41	2.25	0.43	1.11	0.13
RJR238-AM2-A	Inter	0.45	2.56	0.44	1.10	0.14
RJR238-AM2-B	Rim	0.47	2.68	0.45	1.27	0.15
RJR238-AM2-C	Core	0.55	2.89	0.52	1.30	0.17
RJR238-AM2-D	Core	0.56	2.95	0.54	1.31	0.16
RJR238-AM2-E	Rim	0.49	2.68	0.45	1.13	0.14
RJR238-AM3-A	Rim	0.49	2.67	0.47	1.08	0.14
RJR238-AM3-B	Rim	0.51	2.76	0.49	1.17	0.13
RJR238-AM3-C	Core	0.42	2.33	0.41	1.03	0.14
RJR238-AM3-D	Core	0.41	2.53	0.45	1.14	0.13
RJR238-AM3-E	Rim	0.40	2.34	0.40	1.10	0.15
RJR238-AM3-F	Inter	0.44	2.68	0.45	1.15	0.16
RJR238-AM3-G	Rim	0.48	2.45	0.44	1.07	0.13
RJR238-AM4-A	Rim	0.45	2.44	0.44	1.13	0.13
RJR238-AM4-B	Rim	0.44	2.50	0.45	1.06	0.13
RJR238-AM4-C	Inter	0.38	1.99	0.38	0.92	0.12
RJR238-AM4-D	Core	0.36	2.07	0.37	1.03	0.12
RJR238-AM4-E	Core	0.37	1.91	0.36	0.99	0.11
RJR238-AM4-F	Rim	0.37	2.11	0.35	1.00	0.13
RJR238-AM4-G	Rim	0.42	2.30	0.40	1.07	0.13
RJR238-AM4-H	Rim	0.40	2.29	0.39	0.94	0.12
RJR238-AM5-A	Rim	0.42	2.44	0.45	1.24	0.14
RJR238-AM5-B	Rim	0.44	2.56	0.44	1.20	0.14
RJR238-AM5-C	Rim	0.57	3.13	0.52	1.40	0.17
RJR238-AM5-D	Core	0.64	3.38	0.60	1.60	0.22
RJR238-AM5-E	Core	0.51	2.85	0.51	1.38	0.15
RJR238-AM5-F	Rim	0.37	1.91	0.36	0.96	0.12
RJR238-AM5-G	Rim	0.47	2.67	0.50	1.22	0.16

Table B.2: Continued.

Sample-Grain-Spot	Core/Rim	Tb	Dy	Ho	Er	Tm
RJR238-AM5-H	Inter	0.49	2.80	0.47	1.11	0.17
RJR238-AM5-I	Rim	0.63	3.87	0.67	1.78	0.22
RJR238-AM5-J	Core	0.58	3.58	0.58	1.49	0.18
RJR238-AM6-A	Rim	0.61	3.32	0.60	1.61	0.20
RJR238-AM6-B	Rim	0.57	3.28	0.61	1.53	0.16
RJR238-AM6-C	Inter	0.63	3.54	0.61	1.55	0.20
RJR238-AM6-D	Rim	0.63	3.55	0.62	1.70	0.21
RJR238-AM6-E	Inter	0.70	3.96	0.71	1.79	0.22
RJR238-AM6-F	Core	0.93	5.12	0.93	2.15	0.26
RJR238-AM6-G	Core	0.77	4.57	0.80	2.03	0.23
RJR238-AM6-H	Rim	0.68	3.75	0.68	1.76	0.24
RJR239-AM1-A	Rim	0.73	3.90	0.59	1.57	0.21
RJR239-AM1-B	Rim	0.71	4.13	0.64	1.65	0.18
RJR239-AM1-C	Core	0.80	4.54	0.76	1.92	0.22
RJR239-AM1-D	Rim	0.81	4.62	0.79	1.89	0.22
RJR239-AM1-E	Inter	0.82	4.40	0.79	1.78	0.25
RJR239-AM1-F	Rim	0.72	3.89	0.67	1.60	0.19
RJR239-AM2-A	Rim	0.76	4.42	0.69	1.78	0.22
RJR239-AM2-B	Core	0.83	4.61	0.75	1.90	0.26
RJR239-AM2-C	Core	0.88	4.71	0.72	1.91	0.22
RJR239-AM2-D	Core	1.06	5.79	0.93	2.39	0.27
RJR239-AM2-E	Core	0.75	4.46	0.74	1.79	0.22
RJR239-AM2-F	Rim	0.64	3.96	0.64	1.67	0.20
RJR239-AM2-G	Rim	0.65	3.61	0.60	1.48	0.18
RJR239-AM2-H	Inter	0.81	4.20	0.74	1.93	0.22
RJR239-AM2-I	Inter	0.88	5.14	0.81	2.12	0.23
RJR239-AM2-J	Rim	0.74	3.71	0.61	1.72	0.20
RJR239-AM3-A	Rim	0.33	1.80	0.29	0.74	0.09
RJR239-AM3-B	Rim	0.35	1.88	0.32	0.87	0.10
RJR239-AM3-C	Core	0.38	2.14	0.35	0.88	0.11
RJR239-AM3-E	Rim	0.07	0.40	0.06	0.17	0.02
RJR239-AM3-H	Inter	0.19	1.04	0.16	0.43	0.05
RJR239-AM3-I	Rim	0.30	1.65	0.27	0.65	0.08
RJR239-AM3-J	Core	0.29	1.56	0.25	0.59	0.07
RJR240-AM1-A	Rim	0.57	2.78	0.52	1.11	0.14

Table B.2: Continued.

Sample-Grain-Spot	Core/Rim	Tb	Dy	Ho	Er	Tm
RJR240-AM1-B	Core	0.65	3.53	0.56	1.38	0.16
RJR240-AM1-C	Core	0.57	3.20	0.55	1.36	0.18
RJR240-AM1-D	Rim	0.63	3.02	0.54	1.25	0.15
RJR240-AM1-E	Rim	0.51	2.81	0.44	1.23	0.11
RJR240-AM2-A	Rim	0.47	2.42	0.47	1.24	0.14
RJR240-AM2-B	Core	0.46	2.38	0.41	0.90	0.10
RJR240-AM2-C	Core	0.66	3.52	0.56	1.35	0.15
RJR240-AM2-D	Inter	0.46	2.58	0.38	1.05	0.16
RJR240-AM3-A	Rim	0.52	2.97	0.49	1.07	0.14
RJR240-AM3-B	Rim	0.55	2.68	0.49	1.09	0.14
RJR240-AM3-C	Core	0.62	3.44	0.58	1.32	0.17
RJR240-AM3-D	Core	0.56	3.08	0.52	1.13	0.14
RJR240-AM3-E	Inter	0.59	3.33	0.59	1.29	0.13
RJR240-AM3-F	Rim	0.49	2.49	0.42	1.00	0.12
RJR240-AM3-G	Core	0.50	2.94	0.50	1.20	0.15
RJR240-AM4-A	Rim	0.65	3.89	0.63	1.55	0.17
RJR240-AM4-B	Core	0.75	4.05	0.61	1.49	0.17
RJR240-AM4-C	Rim	0.54	2.97	0.53	1.29	0.16
RJR240-AM5-A	Rim	0.74	3.65	0.62	1.30	0.15
RJR240-AM5-B	Inter	0.57	3.06	0.51	1.34	0.15
RJR240-AM5-D	Rim	0.68	3.84	0.57	1.42	0.15
RJR240-AM5-E	Core	0.78	3.85	0.62	1.53	0.14
RJR240-AM5-F	Inter	0.99	5.19	0.80	1.90	0.22
RJR240-AM5-G	Rim	0.68	3.48	0.56	1.34	0.13
RJR240-AM6-A	Rim	0.49	2.68	0.42	1.07	0.10
RJR240-AM6-B	Rim	0.62	3.27	0.51	1.35	0.15
RJR240-AM6-C	Rim	0.21	1.19	0.22	0.40	0.06
RJR240-AM6-D	Rim	0.62	3.21	0.63	1.41	0.15
RJR240-AM6-E	Inter	0.55	3.42	0.52	1.33	0.15
RJR240-AM6-F	Rim	0.52	2.89	0.48	1.11	0.13
RJR240-AM6-G	Core	0.83	4.33	0.67	1.65	0.18
RJR240-AM6-H	Core	0.65	3.35	0.51	1.17	0.14
RJR240-AM6-I	Core	0.65	3.53	0.56	1.34	0.15
RJR240-AM7-A	Rim	0.56	2.91	0.48	1.19	0.16
RJR240-AM7-B	Inter	0.52	2.79	0.45	1.09	0.12

Table B.2: Continued.

Sample-Grain-Spot	Core/Rim	Tb	Dy	Ho	Er	Tm
RJR240-AM7-C	Core	0.73	3.39	0.59	1.21	0.15
RJR240-AM7-D	Rim	0.57	3.38	0.56	1.15	0.15
RJR241-AM2-A	Core	1.24	7.15	1.28	3.22	0.40
RJR241-AM2-B	Core	1.37	7.71	1.40	3.28	0.38
RJR241-AM2-C	Core	0.88	5.14	0.92	2.51	0.29
RJR241-AM2-D	Rim	0.23	1.27	0.23	0.57	0.07
RJR241-AM2-E	Rim	0.30	1.60	0.27	0.78	0.11
RJR241-AM3-A	Rim	0.27	1.57	0.29	0.75	0.10
RJR241-AM3-B	Rim	0.59	3.62	0.67	1.64	0.20
RJR241-AM3-C	Core	0.31	2.08	0.38	0.89	0.10
RJR241-AM3-D	Inter	0.34	2.23	0.40	1.05	0.12
RJR241-AM4-A	Rim	0.83	4.77	0.92	2.29	0.28
RJR241-AM4-B	Core	0.40	2.55	0.43	1.05	0.10
RJR241-AM4-C	Inter	0.22	1.47	0.23	0.64	0.07
RJR241-AM4-D	Core	0.32	1.82	0.32	0.78	0.10
RJR241-AM4-E	Rim	0.94	5.61	1.02	2.36	0.29
RJR242-AM1-A	Rim	0.47	2.90	0.58	1.63	0.20
RJR242-AM1-B	Core	0.48	2.80	0.57	1.48	0.21
RJR242-AM1-D	Inter	0.46	2.87	0.51	1.49	0.20
RJR242-AM2-A	Rim	0.44	2.57	0.50	1.46	0.20
RJR242-AM2-B	Core	0.45	2.85	0.55	1.49	0.20
RJR242-AM2-C	Rim	0.48	2.79	0.53	1.46	0.20
RJR242-AM4-A	Rim	0.54	3.07	0.60	1.60	0.20
RJR242-AM4-B	Core	0.52	3.00	0.54	1.57	0.24
RJR242-AM4-C	Rim	0.51	2.89	0.55	1.50	0.22
RJR243-AM1-A	Rim	0.69	4.07	0.75	1.90	0.22
RJR243-AM1-B	Core	0.61	3.46	0.61	1.68	0.20
RJR243-AM1-C	Core	0.54	3.43	0.63	1.52	0.20
RJR243-AM1-D	Rim	0.60	3.46	0.70	1.93	0.27
RJR243-AM3-A	Rim	0.37	2.25	0.42	1.34	0.22
RJR243-AM3-B	Core	0.40	2.38	0.45	1.30	0.19
RJR243-AM3-C	Core	0.54	3.20	0.59	1.57	0.23
RJR243-AM3-D	Rim	0.61	3.61	0.66	1.86	0.25
RJR245-AM1-A	Inter	6.80	45.31	8.96	27.06	4.09
RJR245-AM1-B	Rim	6.75	44.22	8.88	26.74	3.88

Table B.2: Continued.

Sample-Grain-Spot	Core/Rim	Tb	Dy	Ho	Er	Tm
RJR245-AM1-C	Core	6.95	46.27	9.28	28.65	4.29
RJR245-AM1-D	Rim	6.85	47.72	9.65	29.52	4.42
RJR245-AM1-E	Rim	6.77	45.15	8.93	27.60	4.10
RJR245-AM2-A	Core	7.02	46.48	9.03	25.69	3.65
RJR245-AM2-B	Rim	8.98	59.53	11.61	33.42	4.77
RJR245-AM2-C	Core	14.63	99.22	19.32	55.21	7.75
RJR245-AM2-D	Core	5.99	39.31	7.48	21.58	3.15
RJR245-AM2-E	Rim	17.94	130.13	24.91	74.65	9.92
RJR245-AM2-F	Core	6.72	44.51	8.69	25.07	3.57
RJR245-AM4-A	Rim	6.75	44.15	8.46	24.59	3.72
RJR245-AM4-B	Rim	6.65	43.72	8.55	25.71	3.83
RJR245-AM4-C	Core	6.74	45.82	9.37	28.64	4.35
RJR245-AM4-D	Rim	6.76	46.88	9.47	29.01	4.44

Table B.2: Continued.

Sample-Grain-Spot	Core/Rim	Yb	Lu	Hf	Ta	Th	U
RJR238-AM1-A	Rim	0.83	0.12	2.23	0.57	0.05	0.02
RJR238-AM1-B	Inter	0.85	0.10	2.23	0.86	0.15	0.04
RJR238-AM1-C	Core	0.77	0.11	2.31	0.47	0.06	bdl
RJR238-AM1-D	Rim	0.95	0.12	1.87	0.70	0.08	bdl
RJR238-AM1-E	Core	0.96	0.13	3.71	1.07	0.04	bdl
RJR238-AM1-F	Rim	0.96	0.14	1.97	0.75	0.06	0.03
RJR238-AM1-G	Rim	1.06	0.14	1.93	0.90	0.06	bdl
RJR238-AM1-H	Core	0.72	0.11	1.97	0.37	0.04	0.02
RJR238-AM2-A	Inter	0.98	0.13	2.17	1.22	0.05	bdl
RJR238-AM2-B	Rim	0.80	0.12	1.80	0.67	bdl	0.03
RJR238-AM2-C	Core	0.88	0.16	2.84	2.87	0.24	0.12
RJR238-AM2-D	Core	1.01	0.15	2.26	0.44	0.04	0.02
RJR238-AM2-E	Rim	0.83	0.12	2.42	0.75	bdl	bdl
RJR238-AM3-A	Rim	0.82	0.12	1.66	0.80	0.03	bdl
RJR238-AM3-B	Rim	0.80	0.13	3.39	1.64	0.05	bdl
RJR238-AM3-C	Core	0.81	0.12	1.85	0.37	0.05	bdl
RJR238-AM3-D	Core	0.78	0.12	2.37	0.88	0.04	bdl
RJR238-AM3-E	Rim	0.82	0.12	2.21	0.83	bdl	bdl
RJR238-AM3-F	Inter	0.84	0.12	2.30	0.61	0.03	bdl
RJR238-AM3-G	Rim	0.78	0.10	1.92	0.65	0.05	bdl
RJR238-AM4-A	Rim	0.77	0.12	1.58	1.07	bdl	bdl
RJR238-AM4-B	Rim	0.83	0.10	1.31	1.02	bdl	bdl
RJR238-AM4-C	Inter	0.80	0.10	2.40	1.28	bdl	bdl
RJR238-AM4-D	Core	0.74	0.11	2.56	0.52	0.11	0.03
RJR238-AM4-E	Core	0.69	0.11	2.10	0.22	0.05	bdl
RJR238-AM4-F	Rim	0.62	0.11	2.57	0.68	0.04	bdl
RJR238-AM4-G	Rim	0.80	0.10	2.21	0.58	0.06	bdl
RJR238-AM4-H	Rim	0.71	0.13	2.16	0.91	0.04	bdl
RJR238-AM5-A	Rim	0.85	0.13	2.65	1.14	0.04	0.02
RJR238-AM5-B	Rim	0.85	0.12	2.43	0.91	0.05	bdl
RJR238-AM5-C	Rim	1.20	0.12	2.07	0.56	0.05	bdl
RJR238-AM5-D	Core	1.17	0.17	2.74	0.76	0.10	bdl
RJR238-AM5-E	Core	1.03	0.13	2.76	0.88	0.07	bdl
RJR238-AM5-F	Rim	0.65	0.11	1.89	0.18	0.08	bdl
RJR238-AM5-G	Rim	0.95	0.14	1.90	0.64	0.07	bdl

Table B.2: Continued.

Sample-Grain-Spot	Core/Rim	Yb	Lu	Hf	Ta	Th	U
RJR238-AM5-H	Inter	0.84	0.14	1.99	0.62	0.12	bdl
RJR238-AM5-I	Rim	1.33	0.19	2.15	0.81	0.06	0.04
RJR238-AM5-J	Core	1.03	0.16	2.75	2.48	0.21	0.05
RJR238-AM6-A	Rim	1.47	0.19	0.81	0.98	0.08	0.04
RJR238-AM6-B	Rim	1.04	0.13	2.35	1.49	0.07	0.02
RJR238-AM6-C	Inter	1.10	0.14	2.34	2.05	0.21	0.11
RJR238-AM6-D	Rim	1.51	0.19	1.25	1.51	0.11	0.05
RJR238-AM6-E	Inter	1.32	0.18	1.71	2.00	0.08	0.06
RJR238-AM6-F	Core	1.55	0.21	3.22	3.01	0.26	0.13
RJR238-AM6-G	Core	1.44	0.18	2.29	2.99	0.49	0.23
RJR238-AM6-H	Rim	1.45	0.16	1.60	1.78	0.05	0.05
RJR239-AM1-A	Rim	1.18	0.17	2.49	0.89	1.06	0.28
RJR239-AM1-B	Rim	1.20	0.15	2.34	0.74	0.56	0.15
RJR239-AM1-C	Core	1.47	0.18	2.25	0.89	0.82	0.18
RJR239-AM1-D	Rim	1.34	0.17	3.42	1.62	0.80	0.19
RJR239-AM1-E	Inter	1.33	0.19	6.79	3.07	0.84	0.21
RJR239-AM1-F	Rim	1.28	0.18	2.27	0.78	0.63	0.15
RJR239-AM2-A	Rim	1.42	0.18	2.10	1.28	0.73	0.17
RJR239-AM2-B	Core	1.65	0.21	9.48	4.64	0.83	0.23
RJR239-AM2-C	Core	1.43	0.17	2.91	0.91	0.96	0.24
RJR239-AM2-D	Core	1.68	0.22	4.70	2.54	1.44	0.37
RJR239-AM2-E	Core	1.26	0.18	2.62	1.10	0.71	0.19
RJR239-AM2-F	Rim	1.26	0.16	9.41	3.36	0.66	0.16
RJR239-AM2-G	Rim	1.08	0.16	3.19	1.67	0.62	0.15
RJR239-AM2-H	Inter	1.36	0.19	6.40	2.89	0.75	0.19
RJR239-AM2-I	Inter	1.44	0.20	10.15	3.67	0.93	0.22
RJR239-AM2-J	Rim	1.25	0.16	1.99	2.04	0.63	0.19
RJR239-AM3-A	Rim	0.56	0.07	0.78	0.43	0.35	0.09
RJR239-AM3-B	Rim	0.53	0.07	1.38	0.67	0.32	0.09
RJR239-AM3-C	Core	0.64	0.09	0.95	0.62	0.34	0.09
RJR239-AM3-E	Rim	0.12	0.02	0.23	0.05	0.06	0.01
RJR239-AM3-H	Inter	0.33	0.04	0.82	0.80	0.39	0.10
RJR239-AM3-I	Rim	0.50	0.06	2.03	1.18	0.34	0.08
RJR239-AM3-J	Core	0.48	0.05	1.02	0.72	0.38	0.11
RJR240-AM1-A	Rim	0.92	0.12	2.60	0.96	0.10	0.03

Table B.2: Continued.

Sample-Grain-Spot	Core/Rim	Yb	Lu	Hf	Ta	Th	U
RJR240-AM1-B	Core	0.91	0.11	2.76	1.04	0.08	bdl
RJR240-AM1-C	Core	0.92	0.14	3.19	1.82	0.44	0.22
RJR240-AM1-D	Rim	0.91	0.14	2.99	1.40	0.10	0.04
RJR240-AM1-E	Rim	0.80	0.12	3.19	1.20	bdl	bdl
RJR240-AM2-A	Rim	0.78	0.10	3.59	0.96	bdl	bdl
RJR240-AM2-B	Core	0.63	0.11	3.89	0.64	0.07	bdl
RJR240-AM2-C	Core	0.89	0.10	3.32	0.91	0.08	bdl
RJR240-AM2-D	Inter	0.75	0.10	3.52	0.41	bdl	bdl
RJR240-AM3-A	Rim	0.75	0.10	2.81	0.97	bdl	bdl
RJR240-AM3-B	Rim	0.59	0.10	1.82	1.00	bdl	bdl
RJR240-AM3-C	Core	1.03	0.09	2.91	2.50	0.40	0.11
RJR240-AM3-D	Core	0.78	0.13	3.45	1.83	0.08	0.04
RJR240-AM3-E	Inter	1.02	0.10	3.81	1.58	0.12	bdl
RJR240-AM3-F	Rim	0.71	0.10	4.78	1.99	0.07	bdl
RJR240-AM3-G	Core	0.96	0.10	3.52	1.88	0.24	0.10
RJR240-AM4-A	Rim	0.84	0.14	4.16	2.64	0.22	0.08
RJR240-AM4-B	Core	1.04	0.19	3.86	1.92	0.51	1.20
RJR240-AM4-C	Rim	0.81	0.11	2.21	0.62	0.12	0.13
RJR240-AM5-A	Rim	0.94	0.07	3.51	1.20	bdl	bdl
RJR240-AM5-B	Inter	1.00	0.09	2.66	1.23	0.08	bdl
RJR240-AM5-D	Rim	1.05	0.11	1.11	1.04	0.10	bdl
RJR240-AM5-E	Core	1.21	0.14	3.54	2.42	0.33	0.12
RJR240-AM5-F	Inter	1.31	0.15	5.40	2.38	bdl	bdl
RJR240-AM5-G	Rim	0.82	0.11	1.31	0.88	0.08	0.04
RJR240-AM6-A	Rim	0.72	0.10	2.20	0.88	bdl	bdl
RJR240-AM6-B	Rim	0.82	0.12	2.49	1.19	bdl	bdl
RJR240-AM6-C	Rim	0.46	bdl	2.67	0.53	0.53	0.26
RJR240-AM6-D	Rim	0.83	0.11	3.55	1.54	0.08	bdl
RJR240-AM6-E	Inter	0.81	0.10	2.69	1.44	0.12	bdl
RJR240-AM6-F	Rim	0.73	0.07	3.38	1.32	0.06	bdl
RJR240-AM6-G	Core	1.17	0.16	2.85	1.79	0.71	0.20
RJR240-AM6-H	Core	0.88	0.13	3.40	1.96	0.42	0.21
RJR240-AM6-I	Core	0.81	0.10	3.59	2.00	0.38	0.15
RJR240-AM7-A	Rim	0.91	0.12	1.27	0.42	0.07	bdl
RJR240-AM7-B	Inter	0.77	0.08	1.50	0.72	bdl	bdl

Table B.2: Continued.

Sample-Grain-Spot	Core/Rim	Yb	Lu	Hf	Ta	Th	U
RJR240-AM7-C	Core	0.96	0.14	3.53	2.12	0.35	0.18
RJR240-AM7-D	Rim	1.06	0.14	3.32	1.68	0.08	0.05
RJR241-AM2-A	Core	2.35	0.31	2.44	1.79	0.16	0.06
RJR241-AM2-B	Core	2.31	0.31	4.57	2.34	0.19	0.12
RJR241-AM2-C	Core	1.78	0.21	3.75	1.20	0.20	0.05
RJR241-AM2-D	Rim	0.51	0.08	1.77	0.56	0.43	0.11
RJR241-AM2-E	Rim	0.65	0.09	1.99	1.18	0.41	0.15
RJR241-AM3-A	Rim	0.55	0.08	1.20	0.03	0.28	0.05
RJR241-AM3-B	Rim	1.11	0.15	1.78	0.09	0.16	0.04
RJR241-AM3-C	Core	0.56	0.09	0.82	bdl	0.32	0.06
RJR241-AM3-D	Inter	0.72	0.10	1.64	0.05	0.25	0.07
RJR241-AM4-A	Rim	1.70	0.23	1.96	0.11	0.24	0.11
RJR241-AM4-B	Core	0.59	0.09	1.44	bdl	0.41	0.07
RJR241-AM4-C	Inter	0.46	0.05	0.90	bdl	0.44	0.10
RJR241-AM4-D	Core	0.56	0.07	1.20	0.04	0.32	0.07
RJR241-AM4-E	Rim	1.76	0.20	1.88	0.08	0.58	0.17
RJR242-AM1-A	Rim	1.30	0.19	1.78	1.06	0.10	0.06
RJR242-AM1-B	Core	1.31	0.18	2.25	1.70	0.09	0.04
RJR242-AM1-D	Inter	1.30	0.18	1.85	1.41	0.07	0.01
RJR242-AM2-A	Rim	1.25	0.18	2.15	1.91	0.10	0.02
RJR242-AM2-B	Core	1.28	0.19	2.07	1.75	0.10	0.04
RJR242-AM2-C	Rim	1.22	0.19	1.86	1.59	0.08	0.03
RJR242-AM4-A	Rim	1.35	0.21	2.36	1.79	0.08	0.03
RJR242-AM4-B	Core	1.37	0.20	2.19	2.27	0.07	0.02
RJR242-AM4-C	Rim	1.35	0.21	2.13	1.39	0.08	0.03
RJR243-AM1-A	Rim	1.29	0.18	4.17	1.57	0.12	0.03
RJR243-AM1-B	Core	1.23	0.16	2.50	0.30	0.11	0.03
RJR243-AM1-C	Core	1.17	0.19	2.32	0.19	0.12	0.02
RJR243-AM1-D	Rim	1.71	0.24	0.53	0.14	0.22	0.08
RJR243-AM3-A	Rim	1.63	0.25	0.40	0.05	0.16	0.05
RJR243-AM3-B	Core	1.41	0.21	0.64	0.10	0.12	0.03
RJR243-AM3-C	Core	1.40	0.20	1.10	0.22	0.13	0.04
RJR243-AM3-D	Rim	1.63	0.21	1.38	0.26	0.11	bdl
RJR245-AM1-A	Inter	28.88	4.24	4.69	78.86	0.10	0.05
RJR245-AM1-B	Rim	27.21	3.96	4.17	72.61	0.74	0.05

Table B.2: Continued.

Sample-Grain-Spot	Core/Rim	Yb	Lu	Hf	Ta	Th	U
RJR245-AM1-C	Core	30.76	4.46	5.23	79.45	0.17	0.06
RJR245-AM1-D	Rim	30.82	4.39	4.40	70.33	0.18	0.07
RJR245-AM1-E	Rim	28.44	4.15	4.64	83.90	0.11	0.03
RJR245-AM2-A	Core	23.30	3.15	2.80	102.38	0.50	0.95
RJR245-AM2-B	Rim	29.20	3.51	3.90	112.81	5.23	6.54
RJR245-AM2-C	Core	48.95	6.38	7.85	230.15	2.27	4.94
RJR245-AM2-D	Core	20.30	2.62	3.43	82.51	0.51	1.22
RJR245-AM2-E	Rim	59.80	6.64	5.97	171.33	10.07	21.22
RJR245-AM2-F	Core	23.42	3.03	2.89	95.88	0.40	0.38
RJR245-AM4-A	Rim	26.68	3.71	4.11	70.42	0.06	0.14
RJR245-AM4-B	Rim	27.36	3.95	4.32	83.72	0.15	0.10
RJR245-AM4-C	Core	30.29	4.21	4.30	76.05	0.14	0.06
RJR245-AM4-D	Rim	31.10	4.41	4.28	83.33	0.38	0.91