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Rhyolite Petrogenesis at Tower Mountain Caldera, OR

by

Elizabeth Ann Brown

A thesis submitted in partial fulfillment of the
requirements for the degree of

Master of Science
in
Geology

Thesis Committee:
Martin J. Streck, Chair
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Portland State University
2017

ABSTRACT

Tower Mountain Caldera is the main feature of an Oligocene volcanic field located in the Umatilla National Forest, eastern Oregon. It is perfectly suited to investigate models of rhyolite petrogenesis as all of the important rock components for evaluating generation models are present in a single location and thus are presumably related; basalts, intermediate igneous rocks (which consist of older plutons and younger volcanic rocks, which are ~coeval with rhyolites), metamorphic basement rocks of significant grade, and rhyolites of varying composition. The formation of the caldera produced the Dale Tuff, which comprises the intra-caldera and outflow facies. $^{40}\text{Ar}/^{39}\text{Ar}$ dating places the age of the tuff at 32.66 ± 0.36 Ma. Post-caldera rhyolites erupted along apparent ring fractures and elsewhere. Radiometric U-Pb dating of zircons from three of these rhyolites yielded ages of 32.167 ± 0.020 Ma (#CH07a), 31.798 ± 0.012 Ma (#TM5), and 31.426 ± 0.016 Ma (#CH08a). All rhyolites at Tower Mountain range from low to high silica varieties. Some of the post-caldera rhyolites are chemically similar to the Dale Tuff, such as sample CH07a, and have compositions typical of rhyolites of calc-alkaline volcanic centers (I-type rhyolites), while others are similar to A-type rhyolites (CH08a and TM5). The ages indicate that the calc-alkaline rhyolites were followed by the A-type rhyolites. The petrogenetic relationships between the various rocks types were evaluated. Partial melt modeling based on experimental melts produced from crustal material indicates that batch partial melting of metamorphosed high silica crustal material modified by the addition of more primitive mafic material by assimilation/contamination is the most likely source for the Tower Mountain rhyolites.

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INTRODUCTION

There are two basic models for the petrogenesis of silicic (rhyolitic) magmas. The first model describes a process wherein the silicic melt is derived from basaltic parent magma, either by fractional crystallization alone, or by fractional crystallization combined with assimilation of crustal country rock. This model satisfactorily describes the production of small magma batches. In the other model, which can explain the production of larger magma bodies ($>10^3 \text{ km}^3$), basaltic melts provide heat for the partial melting of crustal rocks (Riley et al., 2001; Bachmann & Bergantz, 2004). Under certain conditions, silicic magmas can be generated via interactions between basaltic melts and metamorphic basement rocks (McCarthy & Patiño Douce, 1997; Streck, 2002). This scenario also involves partial melting of metamorphic rocks, but in addition involves some material exchanges between the crustal protolith and mafic magmas. Either partial melting scenario may be followed by fractional crystallization. The melt expulsion model of Bachmann and Bergantz (2004), also called the “mush model” (Fig. 1), describes a scenario in which the production of voluminous crystal poor rhyolites is a result of the fractional crystallization or partial melting of compositionally intermediate plutonic bodies. As the intermediate magma body reaches approximately 50% crystallinity, the interstitial melt is of rhyolitic composition and the crystal mush becomes static. Being more buoyant, the melt escapes and rises to the top of the magma chamber forming an aphyric “rhyolite horizon”.

Fig. 1 The melt expulsion model, i.e. “mush model”, for the generation of crystal poor rhyolites from Bachmann & Bergantz (2004). This model describes a scenario in which the production of voluminous crystal poor rhyolites is a result of the fractional crystallization or partial melting of compositionally intermediate plutonic bodies.

The Tower Mountain Caldera in Eastern Oregon is perfectly suited to investigate models of rhyolite petrogenesis as all of the important rock components for evaluating generation models are present in a single location and thus are presumably related; basalts, intermediate igneous rocks (which consist of older plutons and younger volcanic rocks, which are approximately coeval with rhyolites), metamorphic basement rocks of significant grade, and rhyolites of varying composition. This study investigates the petrogenetic relationships between these components focusing on which rhyolite generation model applies. The complete record of components provides strong evidence for the origin of the rhyolites at Tower Mountain.

BACKGROUND

Geologic setting and formation of Tower Mountain Caldera

The Tower Mountain (TM) Caldera (Fig. 2) is the main feature of a late Oligocene bimodal volcanic field (Ferns, 2002) located in the Umatilla National Forest of eastern Oregon. This area was mapped in 2001 by Mark Ferns of the Oregon Department of Geology and Mineral Industries (DOGAMI).

Fig. 2 Simplified geologic map of study area (McClaughry et al., 2009). The dashed line indicates the caldera margin. Note the onlapping of the Columbia River basalts to the north and west of the caldera. The intra-caldera facies consist primarily of silicic intrusions and the Dale Tuff. Facies to the south and east consist of other volcanics, metamorphosed accreted terranes, scattered silicic intrusions, and granitic intrusions, also called “stitching plutons”. The map of Oregon (upper right) shows the location of the study area within the state.

The TM volcanic field covers 500 km² in the Blue Mountains Province. Based on previous age information and before our new age dating, the volcanic field was thought to have begun forming around 29.8 Ma where tholeiitic and alkali olivine basalts erupted at the junction between the southern margin of the Mountain Home Metamorphic Complex and the northern margin of the Baker Terrane (McCloughry et al., 2009). The Mountain Home Metamorphic Complex (MHMC) is described as a sequence of medium grade metamorphic rocks of both sedimentary and igneous origin (Anderson, 2013), while the northern margin of the Baker terrane is described as a >25 km wide zone of “fault-bounded, imbricated slabs and slices of meta-igneous and meta-sedimentary rocks faulted into chert-argillite mélange” (Schwartz et al., 2010). Following the initial eruptions was the emplacement of debris flows and the eruption of a series of thick porphyritic dacite and andesite lavas.

The caldera-forming eruptions produced the Dale Tuff, which comprises the intra-caldera and outflow tuff (see Fig. 3 for stages of caldera formation). The subsidence of the caldera produced arcuate ring fractures from which rhyolite domes emerged. Eruptions during this period were of dacitic and rhyolitic composition. On the west side of the caldera these magmas are porphyritic, while the east side is dominated by aphyric magmas and ash flow tuffs. The dacites and rhyolites intruded the intra-caldera tuff and formed the resurgent core (McCloughry et al., 2009). The modern summit of Tower Mountain (2082 m) is located at the center of the resurgent core. While the stratigraphic relationships between volcanic units have not changed, it appears that actual eruption

dates are slightly older and are tighter based on new data presented here (see Results section).

The existence of the caldera was unknown prior to the geologic mapping of this area.

While conducting the necessary fieldwork for map production in 1996, Mark Ferns and William Taubeneck discovered that Tower Mountain was at the center of an approximately 14-kilometer caldera. The intense Tower Mountain Fire of 1995 cleared out the thick lodgepole pine forest that had previously concealed the caldera.

Additionally, aeromagnetic data revealed a low gravity anomaly underlying the core of the caldera (DOGAMI, 2008).

Fig. 3 Stages of caldera formation from Smith & Bailey (1968). I: Regional tumescence generates ring fractures, which are visible at the surface. II: Explosive, caldera-forming eruptions. III: Removal of material causes caldera collapse. IV: Presurgence volcanism occurs, and along with sedimentation, begins to fill the crater. V: Resurgent doming occurs as magma accumulates below the surface. VI: Ring fracture volcanism.

Models and studies of rhyolite generation

McCarthy and Patiño Douce (1997) conducted melting experiments that modeled basaltic underplating of metapelite in order to study the role of basaltic melts in the production of high temperature felsic melts. The researchers found that the intrusion of tholeiitic basalt into metapelite country rock can produce “extensive” chemical interactions. The melts that result from these interactions range in composition from dacite to rhyolite at temperatures as high as 1150°C (McCarthy & Patiño Douce, 1997). This is significant for a few reasons. First, because this temperature is well above the minimum melting temperature for water-saturated granite (i.e. “average” crustal material), secondly, because this violates the generally accepted idea that rhyolites are “cool” melts (750-900°C), and finally, because this provides evidence of felsic melts forming from the interactions between basalt and metamorphic country rock.

Tamura and Tatsumi (2002) describe the bimodal (basaltic and rhyolitic) volcanism of the Izu-Bonin Arc. They suggest that in the case of island arc crust, saturated calc-alkaline andesite forms a source region at depth and this source could then be reheated and remobilized by influxes of basalt. This is an excellent example of a scenario where basalt was not a material source for rhyolitic melt, but provided the necessary heat for partial melting of a compositional intermediate.

Thy, Beard and Lofgren (1990) conducted partial melting experiments on basalts and their metamorphic equivalents in order to determine a suitable protolith for Icelandic

rhyolites, which constitute a rather high proportion of the crustal rock in that region. They found that dehydration melting of amphibolite generated a melt that was very similar to the rhyolites in question. Interestingly, they also state that the K_2O content of the melts is a function of the K_2O content of the starting material and did not find that this was the case for FeO and Al_2O_3 .

The voluminous rhyolites of the Yellowstone Caldera have been studied by Girard and Stix (2009, 2010). In their investigation of the Upper Basin Member rhyolites (2009), they found that these rhyolites were not produced from a single source, but rather originated from six independent magma batches. In their study of the Central Plateau Member rhyolites (2010), they developed a model via trace element geochemical modeling that requires a large “differentiation reservoir” that is heated and replenished episodically by silicic magmas. This process forms smaller magma chambers, which then erupt within a period of a few hundred to a few thousand years. In both of these cases they suggest that the protoliths were themselves silicic, and explain the production of the intra-caldera rhyolites via the crystal mush model.

Szymanowski et al. (2015) investigated the bimodal volcanics of the Yellowstone-Snake River Plain volcanic province. They argue that the scarcity of intermediate volcanics in rhyolitic-basaltic bimodal systems has led to models that require “large degrees” of crustal melting. The authors argue that intermediate melt inclusions found within rhyolitic ignimbrites, as well as mineral phases which are in equilibrium with

intermediate melts, suggest that crustal reservoirs of intermediate composition, which remain mostly unerupted, provide material to the rhyolitic melt via assimilation-fractional crystallization. The addition of less evolved material produces the composition observed in the erupted rhyolites.

Streck (2002) describes the relationship between basalts, metamorphic xenoliths, and the voluminous rhyolitic Rattlesnake Tuff of eastern Oregon. Metasedimentary or metavolcanic lithic fragments are found as inclusions in the tuff and are interpreted as samples of crustal material. This is of relevance to this study as the lithology of these xenoliths is similar to that of the Mountain Home Metamorphic Complex and Baker Terranes, and are likely related to the accreted terranes of the Blue Mountains. Streck suggests that these rhyolites were formed via partial melting of the crust followed by fractional crystallization.

Study relevance and objectives

The Tower Mountain Caldera is petrologically poorly studied despite existing rock exposures providing an unusual combination of all important rock components for evaluating petrogenetic models of rhyolite formation. This study sought to fill this gap by investigating how rhyolites are generated at Tower Mountain. This was done in the context of previously proposed rhyolite petrogenesis models (described above), which were evaluated for their applicability to the TM suite. Given the variety of exposed crustal rocks around Tower Mountain, a second focus was to determine which of the

crustal lithologies makes for a more suitable protolith by partial melting, with or without hybridization.

METHODS

Sampling

Hand samples were collected by M.J. Streck from the study area over a period of three years. Samples were taken from the main rhyolite units and from select units of basaltic to andesitic lava flows of the Tower Mountain volcanic series as established on published geologic maps. In addition to volcanic rocks, all major country rock units were also sampled. Samples were then selected for thin section preparation and whole rock geochemical analysis via XRF and ICP-MS. Samples were selected on the basis of providing wide areal coverage, lithological variation, and freshness of sample (i.e. avoiding altered samples).

Petrographic analysis

Petrographic characteristics of the samples were determined using plane- and crossed-polarized transmitted light. Features from thin section analyses include: mineral occurrences, size, and proportions, as well as mineral and rock textures (see Appendix A).

Bulk rock analysis

Major and trace element analyses were performed at the GeoAnalytical Lab at Washington State University using X-ray Fluorescence (XRF) and Inductively Coupled Plasma-Mass Spectrometry (ICP-MS). Detailed methods and data can be found in Appendix B.

Experimental melts and analysis

During a sabbatical stay of M.J. Streck at the University of Hannover, Germany, a series of melting experiments were performed using a cold seal apparatus in the experimental petrology lab at Hannover. Pressure conditions for all experiments were 500 MPa corresponding to a mid-crustal depth of ~18 km. Temperature ranged from 750 to above 1040°C and water conditions ranged from pure dehydration experiments (no external water added, i.e. dry) to ~6 weight percent. Redox conditions were kept at ~ QFM+2 and experiments lasted on average seven days. Four TM crustal lithologies (biotite schist, biotite fels, amphibolite, and granodiorite) were used as protolith compositions. In addition, intrusions of basaltic to andesitic composition were approximated by mixing protoliths with glasses of differing compositions. This was done to evaluate material exchanges between crustal rocks and intruding magmas. Natural samples of high-alumina basalt (HAOT), Fe rich andesite, and an icelandite from eastern Oregon were chosen. Glasses of all three mafic rocks were produced in the lab at Hannover. The glass component of the experiments were analyzed by Streck at the University of Stuttgart using a CAMECA SX-50 microprobe. Analytical conditions were a 5 µm beam, an

accelerating voltage of 15 kV, a low beam current (8 nA) counting Na and K first for 10 seconds, Ba and P for 30 seconds, and all other elements for 20 seconds.

Analysis of the experimental charges was completed via scanning electron microscope at the Center for Electron Microscopy and Nanofabrication at Portland State University.

The instrument used was the Zeiss Sigma VP FEG SEM, a variable pressure field emission SEM equipped with Oxford EDS/WDS detectors and E-beam lithography system. Energy-dispersive X-ray spectroscopy (EDS) in conjunction with the Oxford AZtec software (2013) was used to determine mineral identification, phase proportions and to produce phase maps. The AZtec software groups materials into phases based on composition, but cannot provide mineral identities. The software does provide the weight percent and atomic percent of the elements in each phase. Atomic percentages were used in formula recalculations to determine phase identities. Backscatter electron (BSE) images were also obtained via the Zeiss Sigma. BSE images provide qualitative compositional data; the shade of grey is an indication of average atomic number (Z). Black areas indicate holes or cracks (no electron return) while white areas indicate a relatively high average Z. Results of these analyses can be found in Appendix A.

Isotopic dating

$^{40}\text{Ar}/^{39}\text{Ar}$ incremental heating experiments were performed at Oregon State University. Crystallization ages on acid-rinsed, fresh feldspars were determined by the $^{40}\text{Ar}/^{39}\text{Ar}$ incremental heating method at the Noble Gas Mass Spectrometry lab at OSU. All

samples were loaded into quartz vials containing small quantities of mineral monitor FCT-3 biotite and irradiated at the OSU TRIGA research reactor. Samples were heated in a double-vacuum, thermocouple-controlled resistance furnace. After each heating step, followed by gas cleanup, the isotopic composition of argon was analyzed using a MAP 215-50 mass spectrometer. ArArCALC software provided by Koppers (2002) was used to reduce the isotopic data and make age calculations. Further details of analytical procedures are described in Duncan and Keller (2004) and on the OSU laboratory website: <http://www.coas.oregonstate.edu/research/mgg/chronology.html>.

Uranium-lead isotopic dating of zircons was completed at the Isotope Geology Laboratory at Boise State University. This was done via laser ablation inductively coupled plasma mass spectrometry. LA-ICP MS also provides trace element concentration data, which can be found in Appendix F. Feldspar was handpicked from mineral separates in order to obtain a common lead correction factor via thermal ionization mass spectrometry (TIMS). Further details of analytical procedures can be found on the BSU laboratory website: <https://earth.boisestate.edu/isotope/analytical-capabilities/>.

Model calculations

Partition coefficients (also called distribution coefficients or D-values) needed for model calculations were selected for the identified mineral phases based on both published and unpublished data. Equation 1 is the general equation for determining a partition

coefficient where D is the partition coefficient, i is a particular element, l is the liquid phase (melt), s is the solid phase (mineral), and C is the concentration of the particular element, i , in either phase l or s :

$$[1] \quad D_i^{l-s} = \frac{C_i^l}{C_i^s}$$

Some partition coefficients for zircon were not found in the literature, and so were calculated using the trace element data obtained via LA-ICP MS collected as part of the U-Pb zircon dating. This was done by determining the average concentration of each trace element in the zircons, then determining the average concentration of each trace element in the bulk rhyolite samples (melt), and dividing the first value by the second. This was done for each rhyolite sample (CH08a, TM5, and CH07a). The results of these calculations were then averaged, and the resulting D -values used in subsequent calculations. Table 1 contains the partition coefficients used in calculations concerning the experimental melts. Table 2 contains the partition coefficients used in calculations concerning basalt sample G314-09-2.

Using the normalized phase proportions (holes and melt phase removed, solid phase proportions recalculated to 100%) provided by AZtec, bulk partition coefficients were calculated for each element using Equation 2, where $\bar{D}$ is the bulk partition coefficient, i is a particular element, s is a particular solid phase (mineral), V is the volume percent

concentration of the particular mineral, and D is the partition coefficient calculated with Equation 1:

$$[2] \quad \bar{D}_i = \sum V_s D_i^s$$

The bulk partition coefficients were then used in calculating the trace element concentrations of the partial melt of the melting experiments. Equation 3 is the partial batch melting equation where C is the concentration of a particular element, i , C^o is the original concentration in the solid mineral phase (and the concentration in the whole system), C^l is the concentration in the liquid phase (melt), D is the bulk partition coefficient, and F is the melt fraction:

$$[3] \quad \frac{C_i^l}{C_i^o} = \frac{1}{D_i^l(1-F)+F}$$

Equation 4 is the partial fractional melting equation where C is the concentration of a particular element, i , C^o is the original concentration in the solid mineral phase (and the concentration in the whole system), C^l is the concentration in the liquid phase (melt), C^s is the concentration remaining in the solid phase, D is the bulk partition coefficient, and F is the melt fraction:

$$[4] \quad \frac{C_i^l}{C_i^s} = \frac{1}{D} (1 - F)^{\frac{1}{(D-1)}}$$

Trace element concentrations were calculated for $\sim \pm 20\%$ the melt percentage contained in a particular experimental melt using both the batch and fractional melting equations. The results of these calculations can be found in Appendix D. The concentration values were then normalized using the primitive mantle normalizing values of Sun and McDonough (1989). The resulting spider diagrams were then compared to those of the parent material and to observed rhyolite compositions in order to determine the model of best fit. These can be found in Appendix D.

To test the viability of rhyolite production via fractional crystallization of basalt, this scenario was also modeled. Equation 5 is Rayleigh fractionation where C is the concentration of a particular element, i , C^o is the original concentration in the solid phase prior to melting (parent), C^l is the concentration after melting (daughter), D is the bulk partition coefficient, and F is the melt fraction remaining:

$$[5] \quad \frac{C_i^l}{C_i^o} = F^{D-1}$$

Trace element concentrations were calculated for remaining melt values of 5% to 1% at intervals of 0.05% using the partition coefficients listed in Table 2. As with the experimental melts, these values were then normalized using the primitive mantle normalizing values of Sun and McDonough (1989). The resulting spider diagrams were then compared to observed rhyolites in order to determine the model of best fit.

Table 1. Trace element partition coefficients for melting calculations

	Cs	Rb	Ba	Th	U	Nb
plagioclase	0.07	0.02	0.5	0.01	0.01	0.01
alkali feldspar	0.052	0.2	7	0.03	0.055	0.03275
quartz	0.005	0.005	0.005	0.005	0.005	0.005
clinopyroxene	0.009	0.01	0.01	0.01	0.01	0.009
orthopyroxene	0.005	0.005	0.005	0.005	0.005	0.005
amphibole	0.01	0.02	0.4	0.01	0.01	1
biotite	0.7	1.5	8	0.005	0.005	1.7
FeTi oxides	0.005	0.05	0.005	0.08	0.08	1.2
apatite	0.7	1.5	0.2	1	1	1.7
zircon	0.005	0.05	0.005	41.84	192.05	1.08
	Ta	La	Ce	Pb	Pr	Sr
plagioclase	0.01	0.3	0.2	0.4	0.18	6
alkali feldspar	0.047	0.138	0.06	0.8	0.048	11.8
quartz	0.005	0.005	0.005	0.005	0.005	0.005
clinopyroxene	0.009	0.2	0.5	0.03	1	0.25
orthopyroxene	0.005	0.01	0.01	0.009	0.015	0.008
amphibole	1	0.5	0.9	0.08	1.5	2
biotite	1.7	0.01	0.01	0.17	0.01	0.6
FeTi oxides	1.4	0.22	0.2	0.1	0.17	0.01
apatite	0.2	46.2	65.7	0.2	70	2
zircon	2	0.24	0.54	0.1	0.5	0.01
	Nd	Zr	Hf	Sm	Eu	Tb
plagioclase	0.15	0.01	0.01	0.1	2.5	0.08
alkali feldspar	0.035	0.03	0.036	0.02	4.75	0.024
quartz	0.005	0.005	0.005	0.005	0.005	0.005
clinopyroxene	2	0.2	0.2	4	4.8	5.5
orthopyroxene	0.02	0.03	0.03	0.04	0.06	0.09
amphibole	2	0.65	0.64	4	4.8	5
biotite	0.01	0.05	0.05	0.01	0.15	0.015
FeTi oxides	0.15	0.8	0.75	0.11	0.13	0.08
apatite	101.5	0.6	0.7	130	155	110
zircon	0.68	3224.17	1589.76	3.42	2.42	33.69
	Dy	Y	Yb	Lu		
plagioclase	0.07	0.07	0.07	0.07		
alkali feldspar	0.024	0.05	0.02	0.016		
quartz	0.005	0.005	0.005	0.005		
clinopyroxene	5	4.8	3.8	3.6		
orthopyroxene	0.18	0.4	0.7	0.65		
amphibole	4.8	4	3.3	2.5		
biotite	0.02	0.03	0.04	0.05		
FeTi oxides	0.09	0.09	0.09	0.1		
apatite	76.2	162	40	20		
zircon	64.89	106.45	385.75	0.1		
Bacon and Druitt, 1988						
Bea et al., 1994						
Broderick, 2008						
Brown, 2013						
Streck and Grunder, 1997						
Streck, unpublished data						

Table 2. Trace element partition coefficients for basalt fractional crystallization calculations

	Cs	Rb	Ba	Th	U	Nb
plagioclase	0.007	0.002	0.05	0.001	0.001	0.001
clinopyroxene	0.0009	0.001	0.001	0.001	0.001	0.0009
FeTi oxides	0.0005	0.005	0.0005	0.008	0.008	0.12
olivine	0.05	0.04	0.03	0.03	0.04	0.01
	Ta	La	Ce	Pb	Pr	
plagioclase	0.001	0.03	0.02	0.04	0.018	
clinopyroxene	0.0009	0.02	0.05	0.003	0.1	
FeTi oxides	0.14	0.015	0.016	0.01	0.017	
olivine	0.03	0.03	0.002	0.0001	0.0002	
	Sr	Nd	Zr	Hf	Sm	
plagioclase	0.6	0.015	0.001	0.001	0.01	
clinopyroxene	0.025	0.2	0.02	0.02	0.4	
FeTi oxides	0.001	0.026	0.08	0.075	0.024	
olivine	0.02	0.0023	0.06	0.04	0.0108	
	Eu	Tb	Dy	Y	Yb	Lu
plagioclase	0.25	0.008	0.007	0.007	0.007	0.007
clinopyroxene	0.48	0.55	0.5	0.48	0.38	0.36
FeTi oxides	0.025	0.019	0.009	0.009	0.018	0.01
olivine	0.03	0.03	0.0263	0.0036	0.0313	0.0383
*Bacon and Druitt, 1988			*Streck and Grunder, 1997			
Fujimaki et al., 1984			*Streck, unpublished data			
Lemarchand et al., 1987			Villemant et al., 1981			
McKenzie and O'Nions, 1987			Estimated or interpolated values			
Nielsen et al., 1992			*Original reference values divided by 10			

RESULTS

VOLCANIC ROCKS

Based on a total alkali-silica classification diagram (LeBas et al., 1986), volcanic samples from the Tower Mountain Caldera range from rhyolite to basalt (Figure 4).

Fig. 4 Tower Mountain volcanic samples plotted onto a total alkali silica (TAS) diagram. The single basalt sample plots on the border between picrobasalt and basalt, indicating low silica content. The rhyolitic samples form a loose cluster between ~6 to 8 weight percent total alkali and ~74 to 80 weight percent silica.

Rhyolite Petrography

Overall, the Tower Mountain rhyolites are typical in terms of mineral assemblage; quartz, alkali feldspar and plagioclase feldspar are the main phases with biotite, amphibole, pyroxene, FeTi oxides, and zircon as accessory phases. In terms of texture, the rhyolites tend to be glassy with sparse phenocrysts. Samples CH08a, CH07, TM5, and CH31 (Dale

Tuff) are described in detail below to illustrate the similarities and differences among the samples.

The groundmass of CH08a is glassy and highly fractured with perlitic texture. There is obvious flow banding. Phenocrysts account for approximately 5-7% of the sample area. Alkali feldspars in the form of sanidine are the most noticeable and largest minerals in the sample, accounting for ~50% of total phenocrysts. These are mostly anhedral, although some have a euhedral shape. These crystals are fractured and have inclusions of FeTi oxides and zircon. Biotite accounts for ~25% of the total phenocrysts. These contain zircon and FeTi oxides inclusions, and are extremely anhedral. Quartz accounts for ~6% of the phenocrysts. It is highly anhedral and highly fractured. Figure 5 is a plane light image of a thin section of CH08a, and Figure 6 is a BSE image of phenocrysts within this sample.

Sample CH07a is composed of a glassy and homogenous groundmass which is light in color, and comprises ~90% of the sample by area, while phenocrysts make up ~10% of the total sample area. The most abundant phenocryst is plagioclase feldspar (andesine) at ~55% modal abundance. Plagioclase phenocrysts are euhedral to subhedral. Iron oxides account for ~30% of phenocrysts, and are found both scattered throughout the sample and as inclusions in biotite. Approximately 15% of phenocrysts are biotite, which are highly fractured. Zircon was observed as an accessory phase and is primarily found as inclusions. Flow structures are visible in the groundmass attesting that it is rhyolite lava

flow. Figure 7 is a plane light image of a thin section of CH07a, and Figure 8 is a BSE image of phenocrysts within this sample.

Fig. 5 Plane light image of a thin section of sample CH08a; rhyolite lava flow. Note the flow banding, perlitic texture, visible phenocrysts, and overall light color. Scale bar is 10 mm. See text for detailed description.

Fig. 6 Backscattered electron (BSE) image of phenocrysts within sample CH08a. The perlitic texture of the groundmass is visible, as are large cracks, indicating a glassy texture. Visible in this image are phenocrysts of titanomagnetite, biotite, alkali feldspar, and zircon. The alkali feldspar and groundmass are of similar shades of grey, indicating similar compositions. Scale bar is 1 mm.

Fig. 7 Plane light image of a thin section of sample CH07a; rhyolite lava flow. Note the homogeneous texture of the groundmass, visible feldspar phenocrysts (discernable by the roughly rectangular shape and faint grey fracture lines), and overall light color. Biotite phenocrysts are too small to be visible at this scale. See text for detailed description.

Fig 8. Backscatter electron (BSE) image of phenocrysts within sample CH07a. Visible in the image is a twinned phenocryst of biotite with an iron oxide inclusion. The groundmass displays flow structures and irregularly shaped holes and cracks, indicating a glassy texture. Scale bar is 500 μm .

The groundmass of sample TM5 is glassy, predominantly transparent, highly fractured, and shows distinctive flow banding. It is darker in color than either CH08a or CH07a.

Phenocrysts are sparse at ~10% of the sample area. The largest and most abundant of the

phenocrysts, ~70%, are alkali feldspar (anorthoclase), which are euhedral to anhedral, tend to be highly fractured, and are found with inclusions of titanoferrite oxides and zircon. Many show compositional zoning. Clinopyroxene phenocrysts are less abundant, ~20%, typically highly euhedral, and fractured. Titanoferrite oxides comprises ~6% of phenocrysts, and zircon, ~4%. Figure 9 is a plane light image of a thin section of TM5. Figure 10 is a BSE image of phenocrysts within this sample.

Fig. 9 Plane light image of a thin section of sample TM5; rhyolite lava flow. Note the flow banding and fine-grained texture of the groundmass, and the sparse, but visible, phenocrysts. Overall, the sample is darker in color than either CH08a or CH07a. See text for detailed description.

Fig. 10
Backscattered electron (BSE) image of phenocrysts within sample TM5. The fine-grained texture of the groundmass is visible as are intersecting cracks, indicating a glassy texture. Visible in this image are phenocrysts of alkali feldspar, clinopyroxene, and titanomagnetite. The scale bar is 1 mm.

The Dale Tuff (CH31) is the outflow tuff of the Tower Mountain Caldera. It has the typical glass shard texture with sparse phenocrysts. A mere 4% of the area is occupied by phenocrysts. Of these, plagioclase feldspar is the most abundant. The normalized mineral assemblage is as follows: ~90% plagioclase feldspar, ~10% oxides, <1% clinopyroxene. The feldspar phenocrysts are euhedral to subhedral and are quite small at just a few millimeters in length. There are abundant small, rounded oxides throughout the sample. Two subhedral pyroxene phenocrysts were observed, which were comparable in size to the feldspar phenocrysts. Very sparse lithic fragments of ~3 mm contain plagioclase laths, euhedral amphibole, and rounded oxides, suggesting that the fragments are basaltic in origin. Figure 11 is a plane light image of a thin section of CH31.

Fig. 11 Plane light image of a thin section of sample CH31, Dale Tuff. The overall texture is glassy with sparse phenocrysts and lithic fragments. See text for detailed description.

Rhyolite Geochemistry

Detailed results of geochemical analysis can be found in Table B1 in Appendix B. The rhyolites have been divided into five groups based on geochemistry and lithology; 1) low silica, 2) A-like, 3) Dale Tuff-like, 4) Dale Tuff, and 5) high silica. It should be noted that there are rhyolites that have silica values similar to those observed in the high and low silica groups, but have not been categorized as such due to some other outstanding characteristic(s). SiO_2 content among all rhyolites ranges from ~73.5% to ~78.9%. FeO^* is consistently low and ranges from ~0.4% to ~1.9%. CaO is also consistently low at ~0.2% to ~1.7%. Na_2O ranges from ~1.4% to 4.1%, and K_2O from ~3.1% to ~6.0%. These ranges are consistent with what is expected for rhyolite.

Figure 12 shows a primitive mantle normalized (Sun and McDonough, 1989) trace element spider diagram for all Tower Mountain rhyolite samples for which ICP MS data was obtained. Overall, the rhyolites show a similar trace element concentration pattern; an overall decrease from Rb to Lu, peaks at U and Pb, and troughs at Ba, Nb, Sr, and Eu.

Fig. 12 Primitive mantle normalized (Sun and McDonough, 1989) trace element spider diagram for all Tower Mountain rhyolite samples for which ICP MS data was obtained. These values are listed in Table 1B.

Figure 13 shows the normalized trace element concentrations on individual spider diagrams for each of the distinct rhyolite groups; low-silica, A-like, Dale Tuff, Dale Tuff-like, and high-silica. Note that the scale is retained from Figure 12 to Figure 13. Although all of the rhyolites show similar patterns of enrichment and depletion, there are subtle but distinct differences among groups. Compared to the primitive mantle, all are 100 times more enriched in the more incompatible elements. This enrichment decreases to just above that observed in the primitive mantle as the elements become less

incompatible. There are exceptions to this trend, most notably at uranium, lead, niobium, strontium, and europium. The uranium peak is relatively small; ~50 times thorium enrichment, except in the case of the low silica group where uranium concentration is ~35 times that of thorium. In contrast, the peaks observed at lead jump back up to ~100 times those observed in the primitive mantle. In the case of the low silica and Dale Tuff-like groups, the rhyolites are more enriched in lead than rubidium. This is also the case for sample TM4 of the high silica rhyolites. Niobium depletion is relatively uniform across the groups showing concentrations around 15 times that observed in the primitive mantle. The exception to this is seen in the A-like rhyolites, where enrichment is ~40 times. The negative anomaly observed at strontium is the greatest for the A-like rhyolites. The Dale Tuff group shows an anomaly at strontium that is similarly strong. For the Dale Tuff-like group and sample TM4 of the high silica group, the negative anomaly at strontium is ~3 times. Sample CH22 of the high silica group does not show a trough at strontium. Strontium concentrations are ~8 times that of the primitive mantle for the low silica group, the highest concentration among the rhyolites. The negative anomalies at europium follow the trends of strontium, being the least pronounced in the low silica group and the most pronounced in the A-like group. A negative anomaly at barium is observed for the A-like rhyolites, the Dale Tuff, and for sample TM4 of the high silica rhyolites. The anomaly is strongest for the A-like rhyolites, varying from ~15 to 32 times that observed in the primitive mantle (excluding sample TM5, which can be seen to vary significantly from the rest of the samples in this group in terms of concentrations for nearly all trace elements).

Fig. 13 Primitive mantle normalized (Sun and McDonough, 1989) spider diagrams of the trace element concentrations of rhyolite samples separated into their respective groups.

It is difficult to discuss the high silica rhyolites as a cohesive group. A cursory examination of Figure 13 reveals that these samples are quite different in terms of trace element concentrations, some of which as been discussed above. In addition to these differences, it should be noted that sample TM4 is more enriched in the less incompatible elements than is sample CH22 by ~3 times.

A-type rhyolites are usually defined as being alkali rich, that is, rhyolites of this type tend to follow the rule $\text{Na}_2\text{O} + \text{K}_2\text{O} > \text{Al}_2\text{O}_3$. However, this is not the only parameter for defining A-type rhyolites; trace element patterns must also be taken into consideration (Whalen et al., 1987). Although the rhyolites here described as “A-like” are not particularly alkali-rich, these samples do show similar trace element concentration patterns as would be expected for A-type rhyolites, specifically in regards to niobium, zirconium, cerium, and yttrium. Though this not particularly apparent in the above spider diagrams, patterns in trace element concentrations are further revealed by element/element scatterplots. These are presented for all rhyolite groups in Figure 14.

Scatterplots A and B in Figure 14 demonstrate how trace element concentrations might be used to delineate A-type and I-type rhyolites (Whalen et al., 1987). Scatterplot A shows how the concentration of niobium varies with the ratio of $1000\text{Ga}/\text{Al}$. The A-like rhyolites (red squares), cluster loosely in the A-type region, with higher concentrations of Nb combined with higher ratios of $1000\text{Ga}/\text{Al}$. The remaining rhyolites cluster tightly (with the exception of high silica sample CH22, blue asterisk) at relatively low

concentrations of niobium with moderate ratios of $1000\text{Ga}/\text{Al}$. Scatterplot B shows that the variation of the niobium with zirconium can also be used to distinguish A-type and I-type rhyolites. Here, the A-like rhyolites show a positive linear relationship between these element concentrations, with a clustering of points at moderately high concentrations of both elements. The I-type rhyolites show two distinct patterns; the Dale-tuff like, Dale Tuff and high silica rhyolites cluster tightly at relatively low concentrations of both niobium and zirconium. The low silica rhyolites (blue triangles) show similar niobium concentrations, but elevated zirconium concentrations.

Scatterplot C of Figure 14 shows the variation of yttrium with cerium. There is a positive linear correlation between these two elements ranging from ~30 ppm cerium and ~13 ppm yttrium to ~118 ppm cerium and ~50 ppm yttrium. The A-type rhyolites again show the most elevated concentrations of both elements. The high silica rhyolites show a marked difference in trace element concentrations with sample CH22 plotting among the Dale Tuff-like rhyolites and sample TM4 plotting with A-like rhyolites. Scatterplot D shows the variation of the sum of the concentrations of cerium, zirconium, niobium, and yttrium with lanthanum. Here, samples fall into a rough positive linear trend from ~24 ppm lanthanum and ~154 ppm $\text{Ce} + \text{Zr} + \text{Nb} + \text{Y}$ to ~57 ppm lanthanum and ~576 ppm $\text{Ce} + \text{Zr} + \text{Nb} + \text{Y}$. The Dale Tuff and Dale Tuff-like rhyolites cluster closely around the lower end of the trend, while the low silica rhyolites show slightly elevated $\text{Ce} + \text{Zr} + \text{Nb} + \text{Y}$ concentrations in comparison. As a group, the A-like rhyolites show the highest concentrations of both $\text{Ce} + \text{Zr} + \text{Nb} + \text{Y}$ and lanthanum as compared to the other rhyolite

groups, the exception being sample CH29, which contains only 23.9 ppm La, the lowest concentration among the samples plotted here. According to Whalen et al., A-type rhyolites contain >350 ppm Ce + Zr + Nb + Y. A-type sample CH30 falls ~50 ppm short of the boundary, but all other A-type samples are at or above the established boundary.

Fig. 14 Element/element variation diagrams for representative rhyolite samples (Table B1). Plots are after Whalen et al., 1987. A shows the variation of niobium with 1000Ga/Al. B shows the variation of zirconium with niobium C shows the variation of yttrium with cerium, and D, the variation of the sum of cerium, zirconium, niobium, and yttrium with lanthanum.

Basaltic Petrography

Sample G314-09-2 was the only basalt sample analyzed from the study area (basalt lava flows are rare among TM volcanic rocks), which, by location and stratigraphy, may be considered as a parent magma for the rhyolites. Sample G314-09-2 is intergranular in texture; the angular interstices between plagioclase grains are occupied by grains of ferromagnesian minerals; olivine, pyroxene, and iron titanium oxides. Phenocryst modal abundance is as follows: ~55% plagioclase, ~40% pyroxene, ~3% olivine, and ~2% Fe-Ti oxides. Figure 15 is a plane light thin section image and Figure 16 is a BSE image of this sample.

Fig. 15 Plane light image of a thin section of sample G314-09-2, basalt. The overall texture is intergranular; interlocking plagioclase feldspar laths (light color minerals) make up the majority of the groundmass with olivine, pyroxene and oxides in the interstitial spaces. See text for detailed description.

Fig. 16 Backscattered electron (BSE) image of basalt sample G314-09-2. The dark gray areas are plagioclase, while black areas represent holes. Note the intergranular texture. There is evidence of significant secondary mineralization and alteration. For example, the high electron return in the cracks, which is likely due to remobilization of calcium by water, and the interstitial dendritic textures.

Geochemistry of basalt and intermediate rocks

Table B2 in Appendix B contains the geochemical data for basaltic and intermediate samples. Figure 17 below shows the normalized trace element concentrations of basalt sample G314-09-2 and intermediate (dacitic) samples CH01 and TM6. These are the only mafic and intermediate samples for which ICP MS trace element concentrations were obtained.

Fig. 17 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram of the trace element concentrations of basaltic (G314-09-2) and intermediate (CH01, TM6) samples.

Isotopic Dating of Rhyolites

U-Pb isotopic dating of zircon and $^{40}\text{Ar}/^{39}\text{Ar}$ isotopic dating of feldspar were utilized to determine the age of the Tower Mountain rhyolites. Images, compositional data, detailed isotopic data and temperature of formation data for the zircons can be found in Appendix F. Figure 18 contains a summary of likely zircon ages which are: 31.426 ± 0.016 Ma for CH08a (A-like), 31.798 ± 0.012 Ma for TM5 (A-like), 32.169 ± 0.024 Ma for CH07a (Dale Tuff-like, I-type), and 32.345 ± 0.01 for MS12-49 (Dale Tuff, I-type). $^{40}\text{Ar}/^{39}\text{Ar}$ dating was performed on the Dale Tuff. The results are listed in Table F3 in Appendix F and shown in Figure 19. The weighted plateau age was determined to be 32.66 ± 0.36 Ma. The ages indicate that the calc-alkaline/I-type rhyolites (Dale Tuff and Dale Tuff-like) were followed by the A-like rhyolites.

Fig. 18 Ages in millions of years of rhyolite samples CH08a (A-like), TM5 (A-like), CH07a (Dale Tuff-like, I-type), and MS12-49 (Dale Tuff, I-type) via chemical abrasion-isotope dilution thermal ionization mass spectrometry (CA-ID TIMS). The colored bars indicate the probability age ranges. n = number of samples, i.e. number of zircon crystals. MSWD = mean square weighted deviation (Schmitz, 2016).

Fig. 19 $^{40}\text{Ar}/^{39}\text{Ar}$ weighted plateau age for the Dale Tuff. The weighted mean ages are calculated by weighting each age analysis by the inverse of the variance. The weighted mean error is calculated using the method of Taylor (1982). The plateau must comprise at least

two contiguous steps and indicates the most probable age, which in this case is 32.66 ± 0.36 Ma.

CRUSTAL ROCKS

Metamorphic Samples

The metamorphic samples range widely in composition and grade. Several of these samples will be discussed in detail in this section.

Sample MS12-47 is a biotite fels, which is a metamorphic rock found in abundance in the study area. It should be noted that the term “fels” is used here in reference to the texture as opposed to the hornfels metamorphic facies. The texture is partially lepidoblastic and partially granoblastic with a pure quartz groundmass. Mineral phase modal abundance is as follows: ~70% quartz, ~13% biotite, ~7% plagioclase (albite), ~8% alkali feldspar (orthoclase), and ~2% muscovite. The mineral assemblage indicates that the protolith may be an immature sandstone. Feldspars show alteration to sericite. Figure 20 is a plane light image of a thin section of MS12-47; Figure 21 is a BSE image.

Fig. 20 Plane light image of a thin section of sample MS12-47, biotite fels. Quartz is the primary mineral phase, which is light gray in color in the above image. See text for detailed description.

Fig. 21 Backscattered electron (BSE) image MS12-47, biotite fels. The texture is partially lepidoblastic with incipient schistosity (left side of image) with a pure quartz groundmass (right side of image). Porphyroblasts are of quartz, biotite, plagioclase, alkali feldspar, and muscovite.

Sample TM13-5 is amphibolite, which is formed when basalt undergoes medium-grade regional metamorphism. It is medium-grained in texture, shows weak to moderate foliation/incipient schistosity, and contains primarily amphibole and plagioclase feldspar with biotite and chlorite as accessory phases. Large hornblende porphyroblasts and actinolite laths make up over 50% of the sample by area. Plagioclase accounts for ~40%; oxides, ~10%, and biotite and chlorite, <1%. Figure 22 is a plane light image of a thin section of TM13-5.

TM13-7 is mica schist. It is medium-grained with strong foliation and contains mainly quartz and biotite, and to a lesser extent, muscovite and chlorite. There are zones that contain only quartz and here the grains are interlocking and show strong undulatory extinction. Chevron-like folds can be seen overprinting the original schistose orientation of the grains. Figure 23 is a plane light thin section image of TM13-7.

Fig. 22 Plane light image of a thin section of sample TM13-5, amphibolite. Weak foliation of mineral grains is visible. The primary mineral phase is amphibole, which lends the sample its overall green hue. The light grey areas are plagioclase. See text for detailed description.

TM13-1 is a biotite schist. It is fine-grained with well-developed foliation. Quartz shows sutured boundaries, and some grains show undulating extinction. Biotite displays moderate parallelism with amphibole porphyroblasts found among biotite laths. Segregation of minerals into mica-rich and quartz-rich domains parallel to the schistosity is observed. There are few (~1-2%) oxides. Figure 24 is a plane light thin section image of sample TM13-1.

Geochemistry of metamorphic samples

Figure 25 shows the normalized trace element concentrations of metamorphic samples for which ICP MS data were obtained. From only brief observation of this figure, it can

Fig. 23 Plane light image of a thin section of sample TM13-7, biotite schist. Strong foliation and chevron-like folding are visible. The light areas are the “quartz only” zones. See text for detailed description.

Fig. 24 Plane light thin section image of TM13-1, biotite schist. The light areas are zones of quartz while the darker areas are biotite. Careful observation also reveals the greenish hue of amphibole. Weak to moderate foliation can be seen. See text for further discussion.

be seen that the metamorphic samples are compositionally diverse. Rubidium enrichment ranges from ~350 times that observed in the primitive mantle (TM13-1, biotite schist) to ~2 times that of the primitive mantle (TM13-5, amphibolite). This diversity of enrichment decreases as incompatibility decreases. That is, there is a narrower range of enrichment values observed for lutetium; all samples fall between ~3 and 10 times the concentrations observed in the primitive mantle. All samples show a peak at barium and uranium and a trough at thorium. Samples MS12-47, TM13-1, TM13-6, TM13-7b peak at lead, while sample TM13-7 (mica schist) displays a negative anomaly and sample TM13-5 (amphibolite) shows neither. Samples TM13-5 and TM13-1 peak at strontium, while samples MS12-47, TM13-7 and TM13-7b show a trough here. TM13-6 (micaceous quartzite) displays neither. Samples TM13-7b (mica schist) and TM13-5 (amphibolite) display mirrored patterns for zirconium and hafnium; a peak and a trough, respectively.

Fig. 25 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram of the trace element concentrations of metamorphic samples. TM13-1 is biotite schist, TM13-5 is amphibolite, TM13-6 is micaceous quartzite, TM13-7 and 13-7b are mica schist, and MS12-47 is biotite fels.

Petrography of plutonic samples

Tower Mountain plutonic rocks are of two types, silicic and intermediate. Examples of the petrography of each type are discussed below.

Sample G314-09-4 is granite with 75.97 weight percent SiO_2 and mineral modal abundance as follows: ~80% quartz, ~15% alkali feldspar, ~3% plagioclase feldspar, ~1% garnet, ~1% biotite, <1% chlorite. The granite displays interlocking grains of quartz with both alkali feldspar and sparse plagioclase feldspar. Some quartz display undulatory extinction. The feldspars are partially seritized. Graphic texture, the intergrowth of quartz and alkali feldspar, is observed. Sparse, yet large (~2 mm), and highly fractured garnet phenocrysts are observed. The undulatory extinction of quartz and presence of chlorite point to low-grade metamorphism. Figure 26 is a plane light image of sample G314-09-4.

Sample TM13-4 is granite with 72.91 weight percent SiO_2 . It displays large, interlocking phenocrysts of quartz, alkali feldspar, plagioclase, and biotite. Feldspars show strong compositional zoning. There are excellent examples of graphic texture and feldspar exsolution lamellae throughout. Accessory chlorite and muscovite are subhedral. The modal abundance of minerals present is as follows: ~60% alkali-feldspar, ~25% quartz, ~10% biotite, <5% plagioclase feldspar, ~1% chlorite, and <1% muscovite. Figure 27 is a plane light thin section image of TM13-4.

Fig. 26 Plane light thin section image of sample G314-09-4, granite. Note the overall light color imparted by felsic minerals and the interlocking texture of phenocrysts. The relatively large and dark “blotchy” areas are fractured garnet phenocrysts. A faint greenish hue is imparted by chlorite and biotite. See text for further discussion.

Fig. 27 Plane light thin section image of TM13-4, granite. Compare to Figure 25. The overall light color is an indication of the abundance of silicic minerals; quartz, alkali-feldspar, and plagioclase feldspar. The greenish brown laths and blades are biotite. See text for further discussion.

Sample TM13-3 is granodiorite with 62.52 weight percent SiO_2 . It is medium to large-grained and the texture is phaneritic. Phenocrysts are of plagioclase feldspar, alkali feldspar, amphibole, biotite, and quartz. Feldspars are both euhedral and subhedral with strong compositional zoning and abundant twinning. This zoning can be seen in Figure 29, which is a BSE image of this sample. Subhedral to anhedral amphibole are located in interstitial spaces. The modal abundance of minerals is as follows: ~25% quartz, ~20% plagioclase feldspar, ~20% alkali feldspar, ~20% amphibole, ~5% biotite, <1% chlorite, <1% apatite. Figure 28 is a plane light thin section image of TM13-3; Figure 29 is a BSE image of the same.

Fig. 28 Plane light thin section image of sample TM13-3, granodiorite. Note the interlocking texture of the phenocrysts and the mix of mafic and felsic minerals, which is characteristic of an intermediate igneous rock. See text for further discussion.

Fig. 29
Backscattered electron (BSE) image of sample TM13-3, granodiorite. Note the interlocking texture of the phenocrysts. The compositional zoning of plagioclase feldspar can be seen.

Sample TM13-9 is diorite with 62.00 weight percent SiO_2 . Figure 30 is a plane light thin section image of this sample. The mineral modal abundance is as follows: ~50% plagioclase feldspar, ~20% biotite, ~10% quartz, ~10% amphibole, ~5% alkali feldspar, ~5% oxides. The texture is phaneritic with some plagioclase phenocrysts greater than 5 mm. Plagioclase is euhedral and shows strong compositional zoning. All other phenocrysts are euhedral to subhedral with oxides being relatively large and equant.

Geochemistry of plutonic samples

All geochemical data can be found in Table B3 in Appendix B. Figure 31 is a primitive mantle normalized (Sun and McDonough 1989) spider diagram of the trace element concentrations of the intermediate and silicic plutonic rocks for which ICP MS data was obtained. All samples are enriched in all trace elements as compared to the primitive mantle. This enrichment varies from ~100 times for Rb and Pb, to just above primitive

Fig. 30 Plane light image of a thin section of sample TM13-9, diorite. This sample contains interlocking plagioclase feldspar, quartz, biotite, and amphibole with accessory oxides. Note the relatively large and highly euhedral plagioclase feldspar, which constitutes the bulk of this sample. See text for further discussion.

mantle concentrations for HREE. All samples except G314-09-4 (granite) show a peak at barium, where this sample shows a negative anomaly. A similar pattern is seen at strontium, but here TM13-2 (granite dike) shows neither a peak nor trough, while all other samples except G314-09-4 show a peak. Samples G314-09-4 and TM13-2 show slight troughs at zirconium. G314-09-4 has a negative europium anomaly; TM13-2 shows a slight anomaly here, as well. It is worth noting that sample TM13-4, which is granite, is geochemically more similar to samples TM13-3 (granodiorite) and TM13-9 (diorite) than it is to the other granitic samples.

Fig. 31 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram of the trace element concentrations of the silicic and intermediate plutonic samples. TM13-2 is a granite dike, TM13-4 is pegmatitic granite, G314-09-4 is granite, TM13-3 is granodiorite, and TM13-9 is diorite.

MODELING RHYOLITE PETROGENESIS

Fractional crystallization

Basalt sample G314-09-2 was used to investigate the possibility of the formation of rhyolites via fractional crystallization. When a basalt undergoes fractional crystallization it takes >90% crystallization for the remaining liquid to reach rhyolitic compositions (Grove and Gerlach, 1982). Therefore, modeling was done only for remaining liquids of 5% or less. The unnormalized results of these calculations are listed in Table 3. Figure 32 shows a primitive mantle normalized spider diagram comparing the results of modeled fractional crystallization of the basalt with the observed trace element concentrations of representative rhyolites. The model produces a flattened pattern where it is compared to that of the rhyolites. For the basalt, a mild peak is seen at barium, which is not shared by the rhyolites. Additionally, the strong lead peak that is shared among all rhyolites is

absent. Troughs occur at thorium, strontium, and europium. Troughs also occur at strontium and europium among the rhyolites. Overall, the fit between the basalt and the rhyolites is unsatisfactory.

Fig. 32 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram of the results of fractional crystallization modeling of basalt sample G314-09-2. The trace element concentrations at differing remaining melt fractions (5-1%) are represented by the greyscale lines with the remaining melt fractions listed in the key.

Table 3. Unnormalized trace element concentrations of basalt fractionation

	melt fraction remaining								
ppm	0.05	0.045	0.04	0.035	0.03	0.025	0.02	0.015	0.01
Rb	158.7	176.3	198.3	226.6	264.2	316.9	395.9	527.4	790.3
Ba	2515.2	2786.2	3124.0	3556.7	4131.2	4931.7	6125.4	8100.3	12010.5
Th	10.3	11.5	12.9	14.8	17.2	20.7	25.8	34.4	51.5
U	3.2	3.5	4.0	4.5	5.3	6.4	7.9	10.6	15.8
Nb	160.5	178.2	200.4	228.9	266.9	320.1	399.8	532.4	797.3
Ta	10.4	11.6	13.0	14.9	17.4	20.8	26.0	34.6	51.8
La	117.6	130.3	146.2	166.5	193.5	231.1	287.2	380.2	564.3
Ce	287.3	318.2	356.7	405.9	471.2	562.2	697.9	922.1	1365.6

Pb	12.1	13.4	15.1	17.2	20.0	23.9	29.7	39.3	58.4
Pr	42.1	46.5	52.1	59.1	68.4	81.3	100.5	132.1	194.1
Sr	2149.6	2304.5	2491.0	2720.8	3012.5	3398.1	3937.9	4762.3	6225.3
Nd	184.9	203.6	226.6	255.9	294.5	347.6	425.9	553.5	800.6
Zr	1601.3	1777.0	1996.3	2277.8	2652.5	3176.0	3959.4	5260.9	7853.0
Hf	41.4	45.9	51.6	58.9	68.5	82.1	102.3	136.0	203.1
Sm	44.6	48.6	53.7	60.0	68.2	79.3	95.5	121.4	170.1
Eu	10.1	10.9	11.8	12.9	14.3	16.1	18.7	22.7	29.7
Tb	7.1	7.7	8.4	9.3	10.5	12.1	14.4	18.0	24.6
Dy	47.0	51.1	56.1	62.4	70.5	81.5	97.3	122.2	168.6
Y	244.0	265.5	291.8	324.8	367.6	425.5	508.9	641.0	887.5
Yb	26.1	28.6	31.6	35.3	40.2	46.9	56.5	72.0	101.3
Lu	4.2	4.6	5.1	5.7	6.5	7.6	9.2	11.7	16.5

PARTIAL MELTING

Experimental melts

The typical rhyolitic mineral assemblage of quartz, alkali feldspar and plagioclase feldspar as main phases, with biotite, amphibole, pyroxene, FeTi oxides, and zircon as accessory phases, is not observed in the majority of experimental melts (see Appendix C). Plagioclase is the dominant feldspar observed, with alkali feldspar being found in only two of the experimental melts. Additionally, quartz is not observed as a distinct mineral phase in the majority of experimental melts. Mineral assemblages that are consistent with dacite (plagioclase feldspar, amphibole, biotite, and pyroxene) are frequently observed. Typical mafic mineral assemblages, such as plagioclase with clinopyroxene, are infrequently observed.

The average major-element concentrations of the glass (i.e. “melt” phase) were determined via electron microprobe. The SiO₂ weight percent and alkali (Na₂O + K₂O)

weight percent were used to classify the experimental melts via the TAS system (LeBas et al., 1986). The summary of these results is found in Table 4. The majority are classified as rhyolite, however, nearly as many melts are classified as dacite. The minority are classified as andesite. Table 4 also contains a summary of the results of partial melt modeling, which is based on the observation and interpretation of the spider diagrams. Common exceptions to “best fit” are HREE, Sr, Eu, Ba, and Th. Exceptions at Zr, Hf, Nd and Pb were also observed. The parent materials for which the batch melt model most closely fits the observed data of the rhyolites are TM13-3 (granodiorite), MS12-47 (biotite fels), and mixtures that contain MS12-47.

Capsule preparation data, backscattered electron images, phase proportions, compositional analysis, etc. for the experimental melts can be found in Appendix C. Four examples of the results of these experiments are presented below.

The glass of experimental melt MS1 contains an average of 73.89% SiO₂ and 8.08% total alkali classifying it as rhyolitic. MS1 produced a mineral assemblage of quartz, orthopyroxene, and pyrite from sample MS12-47 (biotite fels). Figure 33 is a phase map of MS1. The melt occupies ~75% of the total area; phenocrysts are ~25% of the area. The modal abundance of mineral phases is as follows: ~79% quartz, ~21% orthopyroxene, and ~0.2% pyrite. Quartz is euhedral to subhedral and fairly equant, while orthopyroxene presents two morphologies; tabs and laths. Pyrite appears as rounded inclusions in pyroxene.

Fig. 33 Energy dispersive X-ray spectrograph (EDS) map of experimental melt MS1 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; melt, quartz, orthopyroxene, pyrite.

The glass of experimental melt MS4 contains an average of 78.1% SiO₂ and 4.29% total alkali classifying it as rhyolitic. MS4 produced a mineral assemblage of quartz, plagioclase, orthopyroxene, and pyrite from sample MS12-47 (biotite fels). Figure 34 is a phase map of MS4. The melt occupies ~41% of the total area; phenocrysts, ~56%. The modal abundance of mineral phases is as follows: ~75% quartz, ~14% plagioclase, ~11% orthopyroxene, and ~0.02% pyrite. There are two populations of quartz; the first is larger, subhedral, equant, and rounded, while the second is smaller and ranges from rounded and fairly equant to nearly tabular. Orthopyroxene also presents two

morphologies; rounded blocks and laths, with some phenocrysts appearing as intermediates between these. Plagioclase is subhedral and blocky. Pyrite appears as inclusions in orthopyroxene.

Fig. 34 Energy dispersive X-ray spectrograph (EDS) map of experimental melt MS4 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; quartz, melt, plagioclase, orthopyroxene, and pyrite.

The glass of experimental melt MS5 contains an average of 68.62% SiO_2 and 5.70% total alkali, classifying it as dacitic. MS5 produced a mineral assemblage of plagioclase feldspar, orthopyroxene, clinopyroxene, FeTi oxides, and apatite from sample TM13-3 (granodiorite). Figure 35 is a phase map of MS5. The melt occupies ~70% of the sample area; phenocrysts occupy ~27%. The modal abundance of mineral phases is as follows: ~60% plagioclase feldspar, ~26% orthopyroxene, ~5% clinopyroxene, ~2% FeTi oxides,

and ~0.3% apatite. Plagioclase is subhedral to anhedral as is clinopyroxene.

Orthopyroxene presents two morphologies; rounded blocks and laths. FeTi oxides is rather large and rounded in appearance. Apatite is subhedral and rounded; it is seen both as a distinct accessory phase and as inclusions in pyroxene and feldspar. FeTi oxides is rather large and rounded in appearance.

Fig. 35 Energy dispersive X-ray spectrograph (EDS) map of experimental melt MS5 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; melt, plagioclase, orthopyroxene, clinopyroxene, FeTi oxides, apatite.

The glass of MS13 contains an average of 67.26% SiO₂ and 6.16% total alkali, classifying it as dacitic. MS13 produced a mineral assemblage of plagioclase, orthopyroxene, clinopyroxene, and amphibole from TM13-3 (granodiorite). Figure 36 is a phase map of MS13. The melt occupies ~73% of the total area, phenocrysts, ~26%. The

modal abundance of mineral phases is as follows: ~59% plagioclase, ~37% orthopyroxene, ~4% clinopyroxene, ~0.8% amphibole. Plagioclase is subhedral to anhedral, as is clinopyroxene. Orthopyroxene presents two morphologies; rounded blocks and laths. Amphibole is found either as inclusions within plagioclase or is anhedral and rounded in appearance.

Fig. 36 Energy dispersive X-ray spectrograph (EDS) map of experimental melt MS13 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; melt, plagioclase, orthopyroxene, clinopyroxene, and amphibole.

Partial melt models

Detailed results of the batch and fractional partial melt models can be found in Appendix

Fig. 37 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS4. The top graph shows the results of the batch melt model; the bottom shows the results of the fractional melt model. The melt percentages are approximately $\pm 20\%$ that observed in the experimental melt (MS4) as determined by the AZtec software. The trace element concentrations of the parent material, sample MS12-47 (biotite fels), are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH31, which is included for comparison, are indicated by the yellow squares.

Fig. 38 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS13. The top graph shows the results of the batch melt model; the bottom shows the results of the fractional melt model. The melt percentages are approximately $\pm 20\%$ that observed in the experimental melt (MS13) as determined by the AZtec software. The trace element concentrations of the parent material, sample TM13-3 (granodiorite), are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH31, which is included for comparison, are indicated by the yellow squares.

D. Trace element concentrations were calculated for melt percentages that were $\sim\pm 20\%$ that observed in a given experimental melt. Figures 37 and 38 show examples of the results of modeling presented as spider diagrams. From these, the fit of the model can be determined visually. (Spider diagrams for all experimental melts are in Appendix D.) In general, the batch melt model was a better fit than the fractional melt model, although this fit is not perfect. In Figure 37, it can be seen that the Dale Tuff has a trough at barium, which is not captured by the model. Additionally, the europium anomaly is more pronounced in the Dale Tuff than in the model. This is also true, but to a lesser extent, for the trough at strontium. In Figure 38, it can be seen that the model data fails to capture the trace element pattern of the Dale Tuff from rubidium to barium, and again at strontium and europium.

Table 4. Summary of partial melt modeling

experimental melt	parent	SiO ₂ weight percent	Total alkali weight percent	TAS classification	best fit model	notable exceptions to fit
MS1	MS12-47	73.89	8.08	rhyolite	batch	
MS3	TM13-5	69.38	1.89	dacite	neither	
MS4	MS12-47	78.08	4.29	rhyolite	batch	
MS5	TM13-3	68.62	5.70	dacite	batch	
MS6	TM13-5	61.77	1.97	andesite	batch	Sr, Eu
MS8	TM13-3	73.08	6.29	rhyolite	batch	
MS9	TM13-5	58.51	2.78	andesite	batch	
MS13	TM13-3	67.26	6.16	dacite	batch	
MS15	MS12-47	73.20	6.16	rhyolite	batch	
MS16	TM13-3	76.55	6.04	rhyolite	batch	
MS17	TM13-5	70.42	7.06	rhyolite	batch	Sr, Eu
MS18	MS12-47	-	-	-	batch	Eu
MS19	TM13-5	67.83	1.23	dacite	batch	Sr, Eu
MS22	TM13-5	53.25	2.47	basaltic andesite	batch	HREE
MS23	TM13-1	-	-	-	batch	Ba, Sr, Zr, Eu

MS26	50M2C	71.11	7.01	rhyolite	batch	
MS27	50M3A	-	-	-	batch	
MS28	50M3B	62.96	9.93	dacite	batch	
MS29	50M3C	69.83	6.77	dacite	batch	
MS30	50M1A	68.96	5.40	dacite	batch	
MS33	50M1D	-	-	-	batch	HREE
MS34	50M2D	55.34	5.32	basaltic andesite	batch	HREE
MS35	50M3D	55.63	5.51	basaltic andesite	batch	
MS37	TM13-1	65.76	7.55	dacite	batch	Ba, HREE
MS38	TM13-3	71.86	6.98	rhyolite	batch	Sr, Eu
MS39	TM13-3	65.30	5.60	dacite	batch	
MS40	TM13-5	64.17	2.87	dacite	batch	Pb, HREE
MS41	TM13-5	64.93	3.21	dacite	batch	Pb, Zr, Hf, HREE
MS43	50M2B	72.59	7.44	rhyolite	batch	
MS44	50M2C	73.51	7.00	rhyolite	batch	Th
MS45	50M3A	73.14	8.63	rhyolite	batch	
MS46	50M3B	67.39	10.01	dacite	batch	Ba
MS47	50M3C	73.93	7.56	rhyolite	batch	Nd, HREE
MS48	50M3A	71.12	7.25	rhyolite	batch	
MS49	50M3A	70.76	5.61	dacite	batch	
MS50	50M2A	72.23	7.33	rhyolite	batch	
MS51	50M2A	70.26	4.92	dacite	batch	
MS52	50M1A	68.62	4.27	dacite	batch	
MS53	50M1A	63.18	6.75	dacite	batch	
MS55	50M1B	57.75	10.55	trachy andesite	batch	HREE
MS57	50M1D	52.80	4.64	basaltic andesite	batch	HREE
MS58	50M1A	63.98	3.73	dacite	batch	
MS59	50M2C	60.15	5.65	andesite	batch	Th
MS60	MS12-47	72.79	10.78	rhyolite	batch	
MS62	50M2A	-	-	-	batch	Ba
MS63	50M2A	72.88	6.89	rhyolite	batch	
MS65	50MAB	-	-	-	batch	

The glass of the experimental melts was analyzed via EMP. The results of this analysis were used to plot the melts onto a TAS diagram thereby providing the rock type classification. Figure 39 shows the results of the unmodified experimental melts, that is, those to which mafic glass was not added. Sample TM13-5, amphibolite, produced melts

that were of basaltic to dacitic composition. Silica content ranges from 53.25 weight percent to 70.42%. Alkali content ranges from 1.22% to 7.06%. Sample TM13-3, granodiorite, produced melts that were of dacitic to rhyolitic composition. Silica content ranges from 65.30% to 76.55%. Alkali content ranges from 5.60% to 7.00%. Sample MS12-47 (biotite fels) produced melts that were of dacitic to rhyolitic composition. Silica content ranges from 63.98% to 78.08%. Alkali content ranges from 3.73% to 10.78%. Sample TM13-1 (biotite schist) produced a melt that was of trachydacitic composition. Silica content is 65.76% and alkali content is 7.55%. In general, the unmodified experimental melts show a greater variation in silica content than total alkali content.

Figure 40 shows the results of the modified experimental melts, that is, those to which mafic glass was added. Sample TM13-5, amphibolite, produced melts that were of basaltic composition. Silica content ranges from 52.8 weight percent to 55.34%. Alkali content ranges from 4.64% to 5.51%. Sample TM13-3, granodiorite, produced melts that were of andesitic to rhyolitic composition. Silica content ranges from 60.15% to 73.93%. Alkali content ranges from 5.65% to 7.01%. Sample MS12-47 (bitote fels) produced melts that were of dacitic to rhyolitic composition. Silica content ranges from 63.18% to 73.14%. Alkali content ranges from 3.73% to 8.63%. Sample TM13-1 (biotite schist) produced melts that were of trachyandesitic to trachydacitic composition. Silica content ranges from 57.75% to 67.39%. Alkali content ranges from 7.44% to 10.55%. In general, the modified experiment melts also show a greater variation in silica content than total alkali content.

Fig. 39 Unmodified experimental melt glass compositions plotted onto a TAS diagram. The protolith samples are indicated in the key; TM13-5 (amphibolite), TM13-3 (granodiorite), MS12-47 (biotite fels), and TM13-1 (biotite schist).

Fig. 40 Modified experimental melt glass compositions plotted onto a TAS diagram. The protolith samples are indicated in the key; TM13-5 (amphibolite), TM13-3 (granodiorite), MS12-47 (biotite fels), and TM13-1 (biotite schist).

DISCUSSION

TRANSITION FROM CALC-ALKALINE TO A-TYPE RHYOLITES

Calc-alkaline (I-type) rhyolites are low in iron and magnesium while being high in calcium, sodium, and aluminum. They are produced from hydrous, oxidized melts, and are frequently associated with oceanic/continental subduction zones. A-type rhyolites, in contrast, are sub-alkaline to peralkaline, contain relatively high iron/magnesium ratios, as well as high silica, sodium, and potassium. These rhyolites are low in calcium and strontium, while being enriched in the high field strength elements and the rare earth elements, with the notable exception of europium. A-type rhyolites tend to be relatively anhydrous, and are often produced after a previous episode of crustal melting (Elliot, 2003; Whalen, et al., 1987).

Numerous studies (Dorsey and LaMaskin, 2008; Schwartz, et al., 2010; etc.) indicate that the Blue Mountains Province began with the protracted accretion of oceanic terranes onto the existing North American continental crust. Oceanic crustal material is quite hydrous due to interactions with seawater (Elliot, 2003). Assuming that partial melting of this crustal material is the source of the TM rhyolites, it follows that initial rhyolitic eruptions would also be hydrous, and therefore quite explosive, and carry geochemical signatures consistent with subduction. Additionally, mineralogical evidence, i.e. the presence of water-bearing phases such as biotite, indicates that these rhyolites are indeed hydrous.

It is convenient to think of partial melting as a distillation or evolutionary processes, meaning that subsequent eruptions from the same source material will be relatively enriched in the more incompatible elements and depleted in volatiles, such as water, as well as the more compatible elements. As discussed above, the results of isotopic dating of TM rhyolites indicate that the eruption of calc-alkaline (I-type) rhyolites occurred first followed by eruption of A-like rhyolites. This suggests that these two groups of rhyolites are derived from the same source material.

TIMING OF RHYOLITE ERUPTIONS

The results of the $^{40}\text{Ar}/^{39}\text{Ar}$ and U-Pb isotopic dating provide a clear picture of the timing of eruptions for the rhyolite groups. The caldera-forming eruption produced the Dale Tuff (I-type rhyolite), which comprises the intra-caldera and outflow tuff. Isotopic dating places the age of the tuff at 32.66 ± 0.36 Ma ($^{40}\text{Ar}/^{39}\text{Ar}$) and 32.345 ± 0.01 (U-Pb). Post-caldera rhyolites then erupted along apparent ring fractures and elsewhere (see Figure 2). U-Pb dating of zircons from three of these rhyolites yielded ages of 32.169 ± 0.024 Ma for CH07a (Dale Tuff-like/I-type), 31.798 ± 0.012 Ma for TM5 (A-like), and 31.426 ± 0.016 Ma for CH08a (A-like). The ages indicate that the calc-alkaline rhyolites (I-type, Dale Tuff and Dale Tuff-like) were followed by the A-type rhyolites and that effusive rhyolite eruptions restarted without much hiatus after caldera formation.

PARTIAL MELTING MODELS FOR RHYOLITES

Metamorphic rocks as source for rhyolites

The region of the Blue Mountains Province in which the Tower Mountain Caldera formed consists of the Baker Terrane and the Mountain Home Metamorphic Complex. Crustal material in this region is primarily composed of metamorphic rocks along with igneous intrusions (stitching plutons). As has been discussed, partial melting of crustal material is a strong candidate for rhyolite generation. Further evidence of a crustal source is provided by Seligman, et al. (2014) in which the authors investigated stable oxygen isotope signatures of eastern Oregon calderas, including Tower Mountain. They found that TM rhyolites “yield high $^{18}\text{O}_{\text{zircon}}$ values (6.4–7.9 ‰) and normal to low ϵ_{Hf_i} values (5.2–12.6), indicating crustal melting of high- ^{18}O supracrustal rocks.”

Crustal material that may have previously been an unsuitable candidate for rhyolite generation via partial melting may be transformed by metamorphic processes into a more suitable protolith. Three metamorphic samples were used in the production of experimental melts; biotite fels (MS12-47), amphibolite (TM13-5), and biotite schist (TM13-1). Of these three, experimental melts produced from the biotite fels tended toward rhyolitic (Fig. 39). Melts produced from amphibolite were typically dacitic, though andesite, basaltic andesite, and a single rhyolite were also produced. Melts produced from the biotite schist were dacitic. The results of partial melt modeling (Appendix D) support the partial batch melting of biotite fels (MS12-47) as the most likely source of a rhyolitic melt. This is also consistent with the results of calculating incompatible trace element concentrations of the partial melts produced from melting MS12-47 based on observed residual phase proportions (see multiple Figures in

Appendix D). However, the SiO₂ weight percent of this sample is quite high, 80.28%, which is higher than any found in the TM rhyolites, but the SiO₂ of partial melts are lower than the bulk rock composition of MS12-47. The addition of material with a more primitive composition (lower silica, lower concentration of incompatible elements) would help in lowering the silica content of the partial melts to match TM rhyolites, and for inconsistencies observed in the trace element concentration patterns, i.e. the trough observed at barium and the strong europium anomaly (Figs. 37 and 38).

Intermediate plutonic rocks as source for rhyolites

The melt expulsion model of Bachmann and Bergantz (2004), also called the “mush model” (see Figure 1), describes a scenario in which the production of voluminous crystal poor rhyolites, which is an apt description for the Tower Mountain rhyolites, is a result of the fractional crystallization or partial melting of compositionally intermediate plutonic bodies (Bachmann & Bergantz, 2004). As the intermediate magma body reaches approximately 50% crystallinity, the interstitial melt is of rhyolitic composition and the crystal mush becomes static. Being more buoyant, the melt escapes and rises to the top of the magma chamber forming an aphyric “rhyolite horizon”, which then erupts at the surface.

Szymanowski, et al. (2015) found that intermediate melts, which the authors classified as those containing 57-67 weight percent SiO₂, can be found in association with main-stage rhyolitic volcanism. They propose a “fractionation-dominated evolution including some

assimilation”. This type of AFC (assimilation-fractional crystallization) model requires that “significant amounts” of intermediate cumulates remain in the crust. This allows the partial melt to then move towards a rhyolitic composition (Szymanowski et al., 2015).

As can be seen from the results of the experimental melts (Appendix D), partial melting of plutonic intermediate sample TM13-3 (granodiorite) does produce an exceptionally good fit, although only half of the melts produced from this protolith can be classified as rhyolites, with the other half being classified as dacites (see Table 4, Figs. 39 and 40).

Figure 30, which shows the normalized trace element concentrations of intermediate samples (TM13-3, TM13-9), confirms a positive anomaly at both uranium and lead.

However, negative anomalies at barium and europium are absent. The low silica rhyolites (samples CH16 and CH18, which are also classified as I-type) lack a barium trough and show only a mild europium anomaly. It is possible that these rhyolites are the product of partial melting of an intermediate plutonic body, either by melt expulsion or AFC.

FRACTIONAL CRYSTALLIZATION MODEL FOR RHYOLITES

A silicic melt may be derived from a basaltic parent magma, either by fractional crystallization alone, or by fractional crystallization combined with assimilation of crustal country rock. This model satisfactorily describes the production of only small magma batches, and so is not favored for caldera-forming eruptions (Riley et al., 2001; Bachmann & Bergantz, 2004; Szymanowski, et al., 2015). However, the possibility of rhyolite production as the result of the fractional crystallization of basalt was explored via

sample G314-09-2. It can be seen from Figure 32 that the fractional crystallization of basalt produces a poor fit for the rhyolites. Overall, the trace element concentration pattern derived from the fractional crystallization of basalt is quite flat, that is, it lacks the “peaks” and “troughs” seen in the rhyolite spider diagrams. For example, the positive lead anomaly, which is shared among all rhyolite samples, is conspicuously absent in the fractional crystallization model. Fractional crystallization of basalt is thus unlikely the process by which rhyolites were generated. However, underplating of crustal rocks (metamorphic and intermediate plutonic) by basalt is very likely the ultimate cause for rhyolite volcanism, providing the heat necessary to induce partial melting.

CONCLUSIONS

Tower Mountain Caldera is the main feature of an Oligocene volcanic field located in the Umatilla National Forest, eastern Oregon. The TM rhyolites have been divided into five groups based mostly on geochemistry and lithology; 1) low silica (I-type), 2) A-like, 3) Dale Tuff-like (I-type), 4) Dale Tuff (I-type), and 5) high silica (I-type). The formation of the caldera produced the Dale Tuff, which comprises the intra-caldera and outflow tuff. Isotopic dating places the age of the tuff at 32.66 ± 0.36 Ma ($^{40}\text{Ar}/^{39}\text{Ar}$) and 32.345 ± 0.01 (U-Pb). Post-caldera rhyolites then erupted along apparent ring fractures and elsewhere. U-Pb dating of zircons from three of these rhyolites yielded ages of 32.167 ± 0.020 Ma (CH07a), 31.798 ± 0.012 Ma (TM5), and 31.426 ± 0.016 Ma (CH08a). The ages indicate that calc-alkaline rhyolites (I-type) were followed by the A-type rhyolites and that effusive rhyolite eruptions restarted without much hiatus after caldera formation.

Temporal and geochemical data indicate that the I-type and A-type rhyolites are likely derived from the same source material. Partial melt modeling based on experimental melts produced from crustal material indicates that batch partial melting of metamorphosed high silica crustal material modified by the addition of more primitive mafic material by assimilation/contamination is the most likely source. This modeling also suggests that a likely source for the low silica rhyolites is partial melting of Cretaceous plutons of dioritic to granodioritic composition followed by some fractionation to reduce Ba, Sr and Eu. Fractional crystallization of basalt is unlikely the process by which TM rhyolites were generated. However, underplating of crustal rocks (metamorphic and intermediate plutonic rocks) by basalt is very likely the ultimate cause for rhyolite volcanism, providing the heat necessary to induce partial melting.

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APPENDIX A: PETROGRAPHY

VOLCANIC ROCKS

Rhyolites

Fig. A1 Plane light thin section image of sample TM4. Phenocrysts account for ~40% of the area of the sample, with remainder being fine-grained groundmass. The modal abundance of mineral phases is as follows: ~40% quartz, ~40% plagioclase feldspar, ~15% amphibole, and ~5% biotite. Quartz is subhedral and rounded. Plagioclase is euhedral to subhedral and often intergrown. It frequently shows perfect twinning and exsolution lamellae. Amphibole is relatively small and remarkably euhedral. Biotite is relatively small and anhedral.

Fig. A2 Plane light thin section image of sample TM5. This sample is glassy, predominantly transparent, highly fractured, and shows distinctive flow banding. Phenocrysts are sparse at ~10% of the sample area. The largest and most abundant of the phenocrysts, ~70%, are alkali feldspar (anorthoclase), which are euhedral to anhedral, tend to be highly fractured, and

are found with inclusions of titanoferrite oxides and zircon. Many show compositional zoning. Clinopyroxene phenocrysts are less abundant, ~20%, typically highly euhedral, and fractured. Titanoferrite oxides comprises ~6% of phenocrysts, and zircon, ~4%.

Fig. A3 Plane light thin section image of sample CH07a. It is composed of a glassy and homogenous groundmass which is light in color, and which comprises ~90% of the sample by area, while phenocrysts make up ~10% of the total sample area. The most abundant phenocryst is plagioclase feldspar (andesine) at ~55% modal abundance. Plagioclase phenocrysts are euhedral to subhedral. Iron oxides account for ~30% of phenocrysts, and are found both scattered throughout the sample and as inclusions in biotite. Approximately 15% of phenocrysts are biotite, which show heavy weathering. Zircon was observed as an accessory phase and is primarily found as inclusions. Flow structures are visible in the groundmass. These structures, as well as the low abundance and small size of the phenocrysts indicate that CH07a represents a rhyolite flow.

Fig. A4 Plane light thin section image of sample CH31, Dale Tuff. It has the typical glass shard texture with sparse phenocrysts. A mere 4% of the area is occupied by phenocrysts. Of these, plagioclase feldspar is the most abundant. The normalized mineral assemblage is as follows: ~90% plagioclase feldspar, ~10% oxides, <1% clinopyroxene. The feldspar phenocrysts are euhedral to subhedral and are quite small at just a few millimeters in length. There are abundant small, rounded oxides throughout the sample. Two subhedral pyroxene phenocrysts were observed, which were comparable in size to the feldspar phenocrysts. Very sparse lithic fragments of ~3 mm contain plagioclase laths, euhedral amphibole, and rounded oxides, suggesting that the fragments are basaltic in origin.

Fig. A5 Plane light thin section image of sample CH08a. It is glassy and highly fractured with perlitic texture. There is obvious flow banding. Phenocrysts account for approximately 5-7% of the sample area. Alkali feldspars in the form of sanidine are the most noticeable and largest minerals in the sample, accounting for ~50% of total phenocrysts. They are mostly anhedral, although some have a euhedral shape. These crystals are highly weathered, fractured and have inclusions of FeTi oxides and zircon. Biotite accounts for ~25% of the total phenocrysts. These contain zircon and FeTi oxides inclusions, are extremely anhedral, and highly weathered. Quartz accounts for ~6% of the phenocrysts; it is highly anhedral and fractured.

Fig. A6 Plane light thin section image of sample TM13-8. Phenocrysts are large enough to be seen with the naked eye and account for ~20% of the total area. The fine-grained groundmass is composed of quartz and plagioclase laths. Clinopyroxene are subhedral and lath-like, highly fractured and resorbed, and account for ~35% of phenocrysts. Alkali feldspar, accounting for ~25% of phenocrysts, are subhedral, rounded, and often twinned and found in aggregates. Plagioclase feldspar, ~20% of phenocrysts, are subhedral with distinct compositional zoning. Amphibole, ~15%, are euhedral to subhedral, but highly fractured, while orthopyroxene, ~5%, are euhedral but fractured.

Intermediate Rocks

Fig. A7 Plane light thin section image of sample TM6; dacite. The groundmass is primarily of plagioclase laths, which are aligned in the direction of flow, with quartz in the interstices. Phenocrysts, all of which are subhedral to anhedral and fractured, account for ~8% of the total area. The light, irregularly shaped areas are quartz, which account for ~80% of phenocrysts. Clinopyroxene, biotite, and orthopyroxene are also present as phenocrysts at ~10%, ~8% and ~2%, respectively.

Basaltic

Fig. A8 Plane light thin section image of sample G314-09-2. It is intergranular in texture; the angular interstices between plagioclase grains are occupied by grains of ferromagnesium minerals; olivine, pyroxene, and iron titanium oxides. Phenocryst modal abundance is as follows: ~55% plagioclase, ~40% pyroxene, ~3% olivine, and ~2% Fe-Ti oxides.

CRUSTAL ROCKS

Metamorphic Rocks

Fig. A9 Plane light thin section image of sample MS12-47; biotite fels, which is a metasedimentary rock found in abundance in the study area. The texture is partially lepidoblastic and partially granoblastic with a pure quartz groundmass. Mineral phase abundance is as follows: ~70% quartz, ~13% biotite, ~7% plagioclase (albite), ~8% alkali feldspar (orthoclase), and ~2% muscovite. Feldspars show alteration to sericite.

Fig. A10 Plane light thin section image of sample TM13-5; amphibolite. It is medium-grained in texture, shows weak to moderate foliation/incipient schistosity, and contains primarily amphibole and plagioclase feldspar with biotite and chlorite as accessory phases. Large hornblende porphyroblasts and

actinolite laths make up over 50% of the sample by area. Plagioclase accounts for ~40%; oxides, ~10%, and biotite and chlorite, <1%.

Fig. A11 Plane light thin section image of sample TM13-7; mica schist. It is medium-grained with strong foliation and contains mainly quartz and biotite, and to a lesser extent, muscovite and chlorite. There are zones that contain only quartz and here, the grains are interlocking and show strong undulatory extinction. Chevron-like folds can be seen overprinting the original schistose orientation of the grains.

Fig. A12 Plane light thin section image of sample TM13-1; biotite schist. It is fine-grained and shows weak to moderate foliation. Quartz show sutured boundaries, and some grains show undulating extinction. Biotite displays moderate parallelism with amphibole porphyroblasts found among biotite laths. Segregation of minerals into mica-rich and quartz-rich domains parallel to the schistosity is observed. There are few (~1-2%) oxides.

Fig. A13 Plane light thin section image of sample TM13-6; micaceous quartzite. This sample is dominated by interlocking quartz with alkali feldspar and muscovite porphyroblasts. The incipient alteration of the feldspar gives it a cloudy appearance while muscovite has a greenish hue. All mineral grains are elongated and define a diagonal fabric. This texture is a form of schistosity called grain-flattening fabric.

Fig. A14 Plane light thin section image of sample MS12-48; argillite. Argillite is considered as metasedimentary, so is included here among the other metamorphics. Quartz is the dominate phase and displays two populations; a fine-grained equigranular groundmass and larger porphyroblasts, which can be seen as the grey, irregularly shaped patches in the image. Biotite accounts for ~15% of the area. The textured is incipiently lepidoblastic.

Granites

Fig. A15 Plane light thin section image of sample TM13-4; granite. It displays large, interlocking phenocrysts of quartz, alkali feldspar, plagioclase, and biotite. All are euhedral to subhedral. Feldspars show strong compositional zoning. There are excellent examples of graphic texture and feldspar exsolution lamellae throughout. Feldspars are weathering to clay minerals. Accessory chlorite and muscovite are subhedral. The modal abundance of minerals present is as follows: ~60% alkali-feldspar, ~25% quartz, ~10% biotite, <5% plagioclase feldspar, ~1% chlorite, and <1% muscovite.

Fig. A16 Plane light thin section image of sample TM13-2; granite. This sample is similar in appearance and mineralogy to sample TM13-4 with two key differences. First, there are two quartz populations. The first are typical subhedral and interlocking quartz phenocrysts, similar in size and appearance to those observed in TM13-4. The second population are fine-

grained, equigranular porphyroblasts. This population also shows undulatory extinction. The darker green/brown areas between quartz and plagioclase grains are biotite and chlorite. Incipient alignment of these platy minerals is seen. This, along with the equigranular quartz population, indicates incipient metamorphism. The modal abundance of minerals present is as follows: ~60% alkali-feldspar, ~25% quartz, ~10% biotite, <5% plagioclase feldspar, ~1% chlorite.

Fig. A17 Plane light thin section image of sample G314-09-4; granite. Mineral modal abundance as follows: ~80% quartz, ~15% alkali feldspar, ~3% plagioclase feldspar, ~1% garnet, ~1% biotite, <1% chlorite. The granite displays interlocking grains of quartz with both alkali feldspar and sparse plagioclase feldspar. Some quartz show undulatory extinction. The feldspars are in the

processes of breaking down into clay minerals, such as sericite. Graphic texture, the intergrowth of quartz and alkali feldspar, is observed. Sparse, yet large (~2 mm), and highly fractured garnet phenocrysts are observed. The undulatory extinction of quartz and presence of chlorite indicate low-grade metamorphism.

Granodiorites/Diorites

Fig. A18 Plane light thin section image of sample TM13-3; granodiorite. It is medium to large-grained and the texture is phaneritic. Phenocrysts are of plagioclase feldspar, alkali feldspar, amphibole, biotite, and quartz. Feldspars are both euhedral and subhedral with strong compositional zoning and abundant twinning. Subhedral to anhedral amphibole are located in interstitial spaces. The modal abundance of minerals is as follows: ~25% quartz, ~20% plagioclase feldspar, ~20% alkali feldspar, ~20% amphibole, ~5% biotite, <1% chlorite, <1% apatite.

Fig. A19 Plane light thin section image of sample TM13-9; diorite. The mineral modal abundance is as follows: ~50% plagioclase feldspar, ~20% biotite, ~10% quartz, ~10% amphibole, ~5% alkali feldspar, ~5% oxides. The texture is phaneritic with some plagioclase phenocrysts greater than 5 mm. Plagioclase is highly euhedral and shows strong compositional zoning. All other phenocrysts are euhedral to subhedral with oxides being relatively large and squarish.

APPENDIX B: XRF AND ICP MS GEOCHEMICAL DATA

METHODS

X-Ray Fluorescence

Bulk analyses of the rock samples were conducted at the GeoAnalytical Lab at Washington State University (WSU) to determine major and trace element abundances. Fresh portions of the samples were crushed into fine gravel-sized fragments using a Chipmunk Rock Crusher. The samples were then ground into a powder using a tungsten carbide bowl in a swing mill. The powders were homogeneously mixed with dilithium tetraborate ($\text{Li}_2\text{B}_4\text{O}_7$) at a 2:1 flux to rock ratio in a VSM3 vortex mixer. Following the sample preparation and analytical procedures of Johnson et al. (1999), the mixture was then placed in graphite crucibles, fused into glass beads in a muffle furnace at 1000°C, reground with the swing mill, and fused again prior to analysis to ensure complete homogenization. One duplicate bead was prepared for each nineteen samples to verify accuracy of the analysis. A ThermoARL AdvantXP+ sequential X-ray fluorescence (XRF) spectrometer was used to analyze for ten major elements: Si, Ti, Al, Fe, Mn, Mg, Ca, Na, K, and P, and twenty-one trace elements: Ni, Cr, Sc, V, Ba, Rb, Sr, Zr, Y, Nb, Ga, Cu, Zn, Pb, La, Ce, Th, Nd, U, Cs, and As. The X-ray intensity of each element within the prepared glass bead was compared to beads prepared from known standards to determine the unknown concentrations.

Inductively Coupled Plasma Mass Spectrometry

An HP45000 inductively coupled plasma mass spectrometer (ICP-MS) was used for further trace element analyses at the GeoAnalytical Lab at WSU. Analyses were conducted using a 1:1 dilithium tetraborate to rock ratio. The trace elements analyzed were Ba, Rb, Y, Nb, Cs, Hf, Ta, Pb, Th, U, Sr, Zr, and the fourteen naturally occurring rare earth elements (REE): La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, and Lu. The sample preparation and analytical procedures are after Knaack and Hooper (1994)

Table B1. Whole rock geochemical analysis of rhyolites

	Low-silica		A-like					
	CGH16	CGH18	CH08a	CH10	CH27	CH29	CH30	TM5
XRF								
wt%								
SiO ₂	73.5	74	77.5	79.6	78.7	77	77.7	75.2
TiO ₂	0.3	0.3	0.1	0.1	0.1	0.1	0.1	0.2
Al ₂ O ₃	14.4	14.2	12.4	11.6	11.8	12.5	12.3	13
FeO*	1.9	1.7	1.3	0.8	1	1.4	1	1.7
MnO	0	0	0	0	0	0	0	0
MgO	0.3	0.3	0	0	0	0	0	0
CaO	1.7	1.5	0.3	0.2	0.2	0.2	0.4	0.7
Na ₂ O	3.1	3.6	2.4	3.4	3.7	4.1	3.6	2.9
K ₂ O	4.7	4.1	6	4.3	4.5	4.8	4.8	6.3
P ₂ O ₅	0.1	0.1	0	0	0	0	0	0
Total	100	100	100	100	100	100	100	100
XRF								
ppm								
Ni	5.4	5.3	4.3	5	5.9	4.8	7.7	0
Cr	6.4	9.2	3.9	4.6	5.9	5.1	7.1	1.1
Sc	2.8	3.2	0	0.3	0.2	1.3	1.1	1
V	17.1	22.4	1.5	3.3	11.1	3.4	5.1	0.1
Ba	864	828.4	78.7	85.6	98.5	109.6	221.7	1261.9
Rb	82	82.1	116.7	100.8	104.4	106.2	117.3	358.7
Sr	213.6	173.3	12.1	15.2	21.5	20.1	25.1	84.4
Zr	186.9	181.9	228.9	207.8	215.2	246.3	133.4	348.2
Y	16.4	15.2	41.4	33.8	34.7	34.5	25.6	51.1
Nb	11.2	12.9	32.5	30.1	30.3	32.3	26.2	41
Ga	16	17.6	22.9	25.3	22.8	26.8	22.2	25.2
Cu	5.7	8	6.8	5.1	5	4.8	5	1.3
Zn	36.6	40.4	92.2	70.2	47.3	79.8	42.6	130.2
Pb	9.6	10.1	14.7	14	12.8	11.1	13.7	10.6
La	26.6	23.9	40.2	39	43.4	23.9	37.8	56.7
Ce	39.7	45.2	77.4	65.5	80	59.4	66.4	118
Th	6.4	7.4	11.6	10.7	10.1	10.8	11.7	10
Nd	15.6	20	32.7	32.8	39	22	29.1	52.8

XRF								
ratios								
AP	0.7	0.7	0.8	0.9	0.9	0.9	0.9	0.4
Fe/Fe+Mg	0.9	0.8	1	1	1	1	1	1
Ce/Y	2.4	3	1.9	1.9	2.3	1.7	2.6	2.3
ICPMS								
ppm								
La	26.4	28.6	41	40.8	46.4	24.9	38.7	57.1
Ce	42.7	46	81.17	70.6	84.3	62.4	67.8	117.3
Pr	5	5.5	9.64	9.4	10.7	5.6	8.7	14.2
Nd	16.9	19.1	35.63	35.2	39.7	20.7	31	55.2
Sm	3.2	3.6	7.93	7.4	8.4	4.8	6.3	11.7
Eu	0.7	0.7	0.29	0.3	0.3	0.3	0.3	1.5
Gd	2.8	2.9	7.34	6.6	7.3	4.9	5.2	10.5
Tb	0.5	0.5	1.29	1.1	1.2	1	0.9	1.7
Dy	2.8	2.7	7.92	6.6	7	6.5	5.2	10.3
Ho	0.6	0.5	1.55	1.3	1.3	1.4	1	2
Er	1.5	1.4	4.22	3.3	3.5	3.8	2.7	5.3
Tm	0.2	0.2	0.61	0.5	0.5	0.6	0.4	0.8
Yb	1.5	1.4	3.81	2.9	3.2	3.7	2.3	4.5
Lu	0.3	0.2	0.56	0.4	0.5	0.6	0.3	0.7
Ba	868.9	844.6	79.92	84.3	95.2	110.1	220	1299.3
Th	8.1	8.5	11.03	10.7	10.8	11.6	12.4	8.6
Nb	11.5	12.9	34.13	30.9	31.7	33.8	26.4	42.1
Y	15.8	14.6	41.36	32.6	33.9	33.2	24.8	50.7
Hf	5	4.8	7.71	6.9	7.1	7.9	5.3	9.9
Ta	1.2	1.3	2.63	2.5	2.5	2.7	2.4	3
U	2.8	2.9	3.86	3.1	3.9	2.9	3.3	3.2
Pb	11.4	11.3	13.94	14.4	13.1	11.2	14.2	12
Rb	77	78.7	112.51	97.3	99.2	102.6	111.8	360.4
Cs	2.7	2	3.76	2.5	3.5	2	2.3	6.2
Sr	206.2	169.7	13.74	15.4	19.2	19.2	24.2	86.1
Sc	3.2	3.7	0.69	0.7	1	0.9	1.3	1.1
Zr	187.3	180	239.41	207.6	216.1	248.1	132.5	366.5
ICPMS								
ratios								
La/Sm	8.2	8		5.5	5.5	5.2	6.1	4.9
La/Yb	17.5	20.3		14.1	14.6	6.7	16.5	12.6
Ce/Yb	28.3	32.7		24.5	26.5	16.8	28.9	25.9
Ba/Rb	11.3	10.7		0.9	1	1.1	2	3.6

Ba/Sr	4.2	5		5.5	5	5.7	9.1	15.1
Eu/Eu*	0.7	0.7		0.1	0.1	0.2	0.1	0.4
Dale Tuff-like								
	CH02b	CH04b	CH04c	CH05a	CH06b	CH07a	CH07b	
XRF								
wt%								
SiO ₂	76.9	77.7	77.8	77.4	77.5	77.3	77.2	
TiO ₂	0.1	0.1	0.1	0.1	0.1	0.1	0.1	
Al ₂ O ₃	12.9	12.8	13.4	13	12.9	13	12.6	
FeO*	1	0.9	1.1	0.8	0.9	1	1	
MnO	0	0	0	0	0	0	0	
MgO	0.1	0.1	0.3	0.1	0.1	0.1	0.1	
CaO	0.7	0.7	0.9	0.9	0.9	1	0.7	
Na ₂ O	2.5	2.7	1.6	2.7	2.6	2.6	3.9	
K ₂ O	5.8	5.1	4.6	4.9	4.9	4.7	4.4	
P ₂ O ₅	0	0	0	0	0	0	0	
Total	100	100	100	100	100	100	100	
XRF								
ppm								
Ni	3.9	2.6	3.3	3.9	4	3.4	5	
Cr	3	2.6	3.9	3.9	3.5	3.8	6.9	
Sc	2.1	2	2	1.6	2	1.8	2.2	
V	4.7	2	3	4.4	5.6	4.6	4.8	
Ba	867.6	895.7	942.7	939.2	942.2	931.4	912.4	
Rb	96.5	103.5	121.2	94.4	94.7	98	95.7	
Sr	82.9	78.2	101.2	119.3	117.4	122.5	74.4	
Zr	115.9	107.2	109.1	98.1	97	97	100.1	
Y	15.1	15.6	16.3	15.4	16.2	16.1	16.8	
Nb	12	10.9	10.2	10.6	10.8	10.8	11.6	
Ga	14.8	16.5	15.7	14.5	16.8	14.4	16.7	
Cu	4.8	3.6	5.2	4.2	4.3	4.8	6	
Zn	29.9	26.6	32	29	28.8	30.4	33.4	
Pb	12.4	12.2	10.3	12	11.3	11	12.4	
La	26.5	27.8	25.5	26.4	28.1	28.7	27.5	
Ce	45.4	53	45.1	47.9	46.8	47.6	51.7	
Th	8.5	8.3	7.9	8.4	7.5	7.3	8.6	
Nd	15.3	19.8	15.8	16.4	17.3	18	20.1	
XRF								
ratios								
AP	0.8	0.8	0.6	0.8	0.7	0.7	0.9	

Fe/Fe+Mg	0.9	0.9	0.8	0.9	0.9	0.9	0.9
Ce/Y	3	3.4	2.8	3.1	2.9	3	3.1

ICPMS

ppm

La	28.6		27.9		28.1	30.2
Ce	49.9		49.5		48.9	53.3
Pr	5.3		5.2		5.3	5.6
Nd	17.3		17.5		17.6	18.8
Sm	3.2		3.1		3.2	3.4
Eu	0.4		0.4		0.5	0.4
Gd	2.6		2.6		2.7	2.9
Tb	0.4		0.4		0.4	0.5
Dy	2.5		2.6		2.6	2.9
Ho	0.5		0.5		0.5	0.6
Er	1.4		1.4		1.5	1.6
Tm	0.2		0.2		0.2	0.2
Yb	1.5		1.4		1.5	1.6
Lu	0.2		0.2		0.2	0.3
Ba	899.9		937.5		928.8	927
Th	9.5		8.5		8.4	9.6
Nb	12.2		11		10.8	12.1
Y	14.6		14.5		15.1	16
Hf	3.9		3.2		3.2	3.5
Ta	1.4		1.3		1.3	1.4
U	3.3		3		3	3.4
Pb	13.4		13.5		13.3	13.8
Rb	93.8		89.2		93	91.3
Cs	3.3		3.6		3.5	3.4
Sr	82.5		116.4		119	72.6
Sc	1.9		2		2	2
Zr	117.2		95.1		94.4	98.5

ICPMS

ratios

La/Sm	8.9		8.9		8.8	8.8
La/Yb	19.7		19.3		18.9	18.9
Ce/Yb	34.3		34.2		32.9	33.3
Ba/Rb	9.6		10.5		10	10.2
Ba/Sr	10.9		8.1		7.8	12.8
Eu/Eu*	0.4		0.5		0.5	0.4

	Dale Tuff					High-silica		
	CGH31	TM10	CGH32-B	CGH32-F	CGH32-G	CH20	TM4	CH22
XRF								
wt%								
SiO ₂	77.3	77.1	75.2	76.5	76.9	78.7	78.9	77.2
TiO ₂	0.1	0.1	0.2	0.1	0.1	0.3	0.4	0.1
Al ₂ O ₃	12.9	12.7	14.6	13.8	13.2	12	15.5	13.2
FeO*	1	1.3	1.7	1	0.9	0.7	0.4	0.9
MnO	0	0	0	0	0	0	0	0
MgO	0.1	0.1	0.4	0.5	0.3	0.2	0	0.3
CaO	0.6	0.6	1	0.7	0.6	1.3	0.3	1.7
Na ₂ O	2.1	3.5	2.4	1.7	2.3	2.9	1.4	2.2
K ₂ O	5.8	4.7	4.5	5.6	5.7	3.8	3.1	4.5
P ₂ O ₅	0	0	0	0	0	0.1	0	0
Total	100	100	100	100	100	100	100	100
XRF								
ppm								
Ni	5.2	0	8.4	7.8	8	6.4	0.6	2.7
Cr	4.9	2.7	7.9	13.7	3.8	11.2	6.7	3.5
Sc	2.1	2.5	2.9	2.5	2.1	3.3	4.8	2.2
V	3.4	3.8	17.3	5.8	4.8	19.2	29.7	3.5
Ba	611.7	613.3	598.9	562.5	597.9	803.5	450	926
Rb	135	102.6	98.5	107.4	112	73.8	75.7	142.8
Sr	40.5	36	68.4	38.7	36.9	172.6	63.6	236.5
Zr	92	85	105.4	92	89.6	143.8	129.4	88
Y	19.2	14.7	20.2	21.5	19.1	14.7	37.1	13.5
Nb	13.2	13.6	13.4	12.1	13.6	10.9	14.4	9.1
Ga	16	16.2	17.7	17.7	17.3	14.8	18.4	13.8
Cu	6.3	0.9	9.7	6.9	7	5.4	18.7	3
Zn	32.5	15.8	40.2	21.9	30.4	16.3	9	31.9
Pb	13.9	14.3	13.4	7.1	7.9	9.4	13.3	9.9
La	35.4	32	28.7	35.9	31.1	23.4	32.5	24.6
Ce	56.8	56.7	56.2	61.1	53.7	36.1	66.2	45
Th	10.8	12	9.3	9.6	10.5	5.6	11.8	9
Nd	20.5	18.1	19.7	21.9	19.3	14.1	32.6	16.1
XRF								
ratios								
AP	0.8	0.5	0.6	0.6	0.8	0.7	0.8	0.6
Fe/Fe+Mg	0.9	0.9	0.8	0.7	0.8	0.8	1	0.8

Ce/Y	3	3.9	2.8	2.8	2.8	2.5	1.8	3.3
ICPMS								
ppm								
La	33.7	32.1	31.9		32.1		32.3	25.5
Ce	58.8	56.3	55.9		57.4		64.2	43.4
Pr	6.4	6	6.1		6.2		8.6	4.5
Nd	21.2	20	20.9		20.6		32	14.8
Sm	3.9	3.5	3.9		3.9		7.3	2.7
Eu	0.3	0.3	0.4		0.3		1.1	0.4
Gd	3.4	2.9	3.4		3.3		6.1	2.3
Tb	0.5	0.5	0.6		0.5		1.1	0.4
Dy	3.3	2.7	3.5		3.3		6.8	2.2
Ho	0.7	0.5	0.7		0.7		1.4	0.5
Er	1.9	1.4	1.9		1.8		3.9	1.3
Tm	0.3	0.2	0.3		0.3		0.6	0.2
Yb	1.9	1.4	2		1.9		3.9	1.3
Lu	0.3	0.2	0.3		0.3		0.6	0.2
Ba	615.5	623.3	602.5		603.8		455.3	937.9
Th	11	10.8	10.2		11		9.4	9.3
Nb	13.9	13.5	13.6		14.1		14.5	9.6
Y	18.7	14.5	19.2		18.8		35.6	13.2
Hf	3.5	3.4	3.6		3.4		4.1	3.1
Ta	1.6	1.5	1.5		1.6		1.4	1.1
U	3.9	2.7	3.5		3.9		4.8	3.2
Pb	15	14.7	13.8		9.1		12.1	12
Rb	126.9	102.8	94.1		106.2		75.6	135.9
Cs	4.4	3.4	4.8		4.1		3.1	5.3
Sr	39.2	36.9	67.1		36.2		63.3	230.4
Sc	2.5	2.1	4.3		3.1		4.1	1.7
Zr	91	89.9	102.5		88.3		129.4	87.7
ICPMS								
ratios								
La/Sm	8.6	9.1	8.2		8.3		4.4	9.5
La/Yb	18.1	23.1	16.3		17.2		2.7	6
Ce/Yb	31.6	40.5	28.6		30.8		16.3	33.1
Ba/Rb	4.9	6.1	6.4		5.7		6	6.9
Ba/Sr	15.7	16.9	9		16.7		7.2	4.1
Eu/Eu*	0.2	0.3	0.4		0.2		0.5	0.5

Table B2. Whole rock geochemical analysis of basalt and dacites

	basalt	dacite	dacite
	G314-09-2	CH01	TM6
XRF wt%			
SiO ₂	48.05	64.88	68
TiO ₂	1.937	0.808	0.612
Al ₂ O ₃	16.61	16.74	17.05
FeO*	12.07	4.01	2.72
MnO	0.171	0.044	0.039
MgO	7.85	1.84	0.94
CaO	10.33	4.80	4.83
Na ₂ O	2.48	4.51	3.74
K ₂ O	0.34	2.05	1.9
P ₂ O ₅	0.168	0.327	0.158
Total	100	100.00	100
XRF ppm			
Ni	134	30	8
Cr	177	47	23
Sc	29	11	10
V	221	79	75
Ba	135	696	827
Rb	8	48	39
Sr	281	505	485
Zr	83	198	121
Y	22	21	15
Nb	7.4	17.7	7
Ga	14	20	16
Cu	147	20	13
Zn	94	54	50
Pb	0	6	8
La	6	25	18
Ce	16	47	29
Th	2	3	3
Nd	14	23	16
U	0		
ICPMS ppm			
La	6.35	28.04	15.92
Ce	15.79	47.35	29.34

Pr	2.45	6.11	3.64
Nd	12.09	22.71	14.17
Sm	3.68	4.56	3.05
Eu	1.37	1.27	0.92
Gd		4.03	2.73
Tb		0.64	0.45
Dy	4.36	3.72	2.7
Ho		0.73	0.52
Er		1.99	1.42
Tm		0.28	0.2
Yb	2.1	1.82	1.23
Lu	0.33	0.28	0.21
Ba	137	695	836.92
Th		4.72	3.07
Nb		18.47	7.16
Y	22.05	19.87	13.61
Hf	2.14	4.60	3.16
Ta	0.53	1.27	0.51
U	0.16	1.78	1.29
Pb	0.65	8.04	8.13
Rb	8	45.2	38.65
Cs	1.53	0.95	1.92
Sr	297	496	480.22
Sc		10.7	8.82
Zr	83	196	121.43

Table B3. Whole rock geochemical analysis of crustal rocks

	biotite schist	amphibolite	mica schist	mica schist	biotite fels	argillite	micaceous quartzite
	TM13- 1	TM13-5	TM13-7	TM13-7b	MS12- 47	MS12- 48	TM13-6
XRF							
wt%							
SiO ₂	46.63	47.22	56.7	33.58	80.28	85.31	72.78
TiO ₂	1.564	0.932	0.763	1.01	0.471	0.507	0.477
Al ₂ O ₃	18.05	17.85	15.18	29.23	9.47	7.94	14.3
FeO*	14.98	10.21	9.18	23	3.49	2.2	3.98
MnO	0.222	0.213	0.202	0.312	0.06	0.011	0.085
MgO	7.54	8.76	9.39	7.58	2.02	0.81	1.59
CaO	3.33	12.49	2.11	0.8	0.4	0.68	2.72
Na ₂ O	1.91	2	4.4	0.54	1.01	1.31	3.7
K ₂ O	5.62	0.14	1.96	3.73	2.72	1.18	0.25

P2O5	0.147	0.184	0.122	0.22	0.081	0.04	0.117
Total	100	100	100	100	100	97.33	100
XRF							
ppm							
Ni	106	75	161	11	11	7	3
Cr	269	265	209	2	51	46	4
Sc	50	45	25	18	12	11	14
V	389	333	182	85	116	200	35
Ba	3597	45	532	1982	2374	563	291
Rb	232	1	52	39	66	39	3
Sr	204	323	38	40	72	105	188
Zr	87	39	81	223	89	103	114
Y	30	18	18	26	17	26	32
Nb	10.4	2.7	3.2	7.2	7.4	9.3	3.8
Ga	25	18	17	32	16	12	15
Cu	60	24	18	4	58	19	7
Zn	186	81	113	295	78	53	52
Pb	6	2	2	2	7	11	2
La	6	5	7	0	22	22	9
Ce	18	16	18	3	38	40	19
Th	1	0	1	3	7	7	1
Nd	13	12	11	4	18	22	11
U	1	0	1	1	3	4	0
ICPMS							
ppm							
La	5.18	16.81	6.76	0.91	19.87	22.44	8.21
Ce	12.74	32.93	15.49	3.23	40.26	40.42	18.22
Pr	1.99	4.13	2.23	0.59	4.68	5.39	2.62
Nd	10.01	16.61	10.18	3.23	17.23	20.83	11.98
Sm	3.21	3.54	2.73	1.16	3.34	4.33	3.51
Eu	1.03	1.07	0.81	0.47	0.6	1.1	1.1
Gd	4.25	3.15	3.01	2.12	2.87	4.02	4.36
Tb	0.78	0.48	0.53	0.41	0.47	0.64	0.78
Dy	5.23	2.86	3.42	3.1	2.96	3.99	5.28
Ho	1.13	0.57	0.72	0.82	0.61	0.84	1.13
Er	3.1	1.58	2.03	2.85	1.71	2.34	3.35
Tm	0.45	0.22	0.3	0.5	0.26	0.34	0.5
Yb	2.66	1.4	1.97	3.81	1.69	2.14	3.23
Lu	0.42	0.23	0.3	0.72	0.28	0.36	0.52
Ba	3559	734	535	1935	2483	578	297

Th	0.33	3.78	1.74	2.46	7.06	6.68	1.41
Nb	8.56	5.68	3.26	5.26	7.23	8.39	2.68
Y	27.82	14.99	17.43	26.45	15.47	23.75	29.84
Hf	2.23	2.69	2.34	6.08	2.39	2.88	3.29
Ta	0.33	0.47	0.21	0.35	0.63	0.64	0.19
U	0.21	1.47	0.69	0.78	2.29	3.24	0.5
Pb	5.35	6.63	0.39	1.29	5.46	8.83	1.53
Rb	220.9	43.7	51.2	38.4	65.7	40	2.8
Cs	22.22	3.8	1.65	0.55	3.87	3.17	0.1
Sr	209	574	39	43	73	111	196
Sc	50.1	14.9	25.6	19.3	12	11.6	13.1
Zr	77	99	82	216	89	106	116
	granite	granite	granite	granodiorite	diorite		
	TM13-2	TM13-4	G314-09-4	TM13-3	TM13-9		
XRF							
wt%							
SiO2	77.14	72.91	75.87	62.52	62		
TiO2	0.095	0.23	0.022	0.703	0.667		
Al2O3	13.39	15.28	14.74	16.82	16.39		
FeO*	0.36	1.53	0.73	5.39	5.53		
MnO	0.013	0.029	0.033	0.098	0.104		
MgO	0.1	0.58	0.06	3.02	3.73		
CaO	1.09	2.71	1.23	5.7	6.42		
Na2O	3.79	4.23	6.37	3.69	3.47		
K2O	3.98	2.39	0.91	1.85	1.53		
P2O5	0.046	0.108	0.037	0.2	0.16		
Total	100	100	100	100	100		
XRF							
ppm							
Ni	4	3	0	18	35		
Cr	5	4	2	40	73		
Sc	3	3	3	15	18		
V	8	13	3	135	147		
Ba	1203	1063	195	736	487		
Rb	78	41	26	46	40		
Sr	201	488	76	567	501		
Zr	54	105	51	101	112		
Y	13	10	20	16	17		
Nb	6.7	4.5	6.2	6.4	4.6		
Ga	14	16	17	19	17		

Cu	2	7	16	24	40
Zn	5	27	11	69	70
Pb	23	13	16	7	6
La	23	11	16	16	11
Ce	35	20	29	32	28
Th	8	2	8	5	2
Nd	11	9	12	15	16
U	4	1	4	3	1

**ICPMS
ppm**

La	19.55	11.95	16.71	16.81	12.18
Ce	33.85	20.6	32.4	32.93	26.17
Pr	3.57	2.3	3.65	4.13	3.55
Nd	11.88	7.89	12.96	16.61	15
Sm	2.23	1.56	2.84	3.54	3.34
Eu	0.46	0.7	0.16	1.07	0.96
Gd	1.89	1.36	2.81	3.15	3.2
Tb	0.32	0.23	0.52	0.48	0.51
Dy	2.03	1.4	3.36	2.86	2.95
Ho	0.41	0.29	0.68	0.57	0.6
Er	1.18	0.85	1.88	1.58	1.64
Tm	0.19	0.13	0.28	0.22	0.23
Yb	1.21	0.92	1.81	1.4	1.48
Lu	0.19	0.15	0.27	0.23	0.23
Ba	1235	1083	200	734	483
Th	8.87	2.72	6.17	3.78	2.71
Nb	6.27	4.29	5.78	5.68	4.02
Y	12.37	8.55	19.69	14.99	15.73
Hf	1.93	2.66	2.39	2.69	2.98
Ta	0.94	0.37	0.96	0.47	0.3
U	2.94	1.74	3.45	1.47	0.91
Pb	20.61	12.06	16.7	6.63	5.19
Rb	79.9	40.9	26.8	43.7	38.2
Cs	2.31	2.09	0.43	3.8	1.74
Sr	215	506	79	574	503
Sc	2	1.8	2.2	14.9	16.3
Zr	58	108	55	99	109

APPENDIX C: EXPERIMENTAL MELTS

NOTES

The label “magnetite” on EDS phase maps is used generally to refer to FeTi oxides.

Figure C2: Due to the limitations of the AZtec software, some of the phase which is labeled as “clinopyroxene” likely should belong to the “melt” phase. This discrepancy can be seen by comparing the EDS map with the BSE image, i.e. the darker shade of grey surrounding the lighter phenocrysts of clinopyroxene.

Figure C11: Due to the limitations of the AZtec software, some of the phase which is labeled as “melt” likely is biotite. This is based on the reflectivity of the BSE image and compositional analysis of this phase.

Figure C47: The BSE image and EDS map do not correspond, however, these are representative of the same sample (MS65). This BSE image was selected because it was the clearest and most representative of all those obtained.

Fig. C2 Top: Backscatter electron (BSE) image of experimental melt MS3. The shade of grey is an indication of average atomic number (Z); black areas indicate holes or cracks (no electron return) while white areas indicate a relatively high average Z.

Left: Energy dispersive X-ray spectrograph (EDS) map of MS3 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; clinopyroxene, plagioclase, melt.

Fig. C3 Top: Backscatter electron (BSE) image of experimental melt MS4. The shade of grey is an indication of average atomic number (Z); black areas indicate holes or cracks (no electron return) while white areas indicate a relatively high average Z.

Left: Energy dispersive X-ray spectrograph (EDS) map of MS4 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; quartz, melt, plagioclase, orthopyroxene, pyrite.

Fig. C4 Top: Backscatter electron (BSE) image of experimental melt MS5. The shade of grey is an indication of average atomic number (Z); black areas indicate holes or cracks (no electron return) while white areas indicate a relatively high average Z.

Left: Energy dispersive X-ray spectrograph (EDS) map of MS5 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; melt, plagioclase, orthopyroxene, clinopyroxene, FeTi oxides, apatite.

Fig. C5 Top: Backscatter electron (BSE) image of experimental melt MS6. The shade of grey is an indication of average atomic number (Z); black areas indicate holes or cracks (no electron return) while white areas indicate a relatively high average Z.

Left: Energy dispersive X-ray spectrograph (EDS) map of MS6 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; melt, plagioclase, orthopyroxene, apatite, FeTi oxides.

Fig. C6 Top: Backscatter electron (BSE) image of experimental melt MS8. The shade of grey is an indication of average atomic number (Z); black areas indicate holes or cracks (no electron return) while white areas indicate a relatively high average Z.

Left: Energy dispersive X-ray spectrograph (EDS) map of MS8 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; melt, orthopyroxene, clinopyroxene, apatite, zircon, amphibole.

Fig. C7 Top: Backscatter electron (BSE) image of experimental melt MS9. The shade of grey is an indication of average atomic number (Z); black areas indicate holes or cracks (no electron return) while white areas indicate a relatively high average Z.

Left: Energy dispersive X-ray spectrograph (EDS) map of MS9 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; melt, clinopyroxene, orthopyroxene, FeTi oxides, apatite.

Fig. C8 Top: Backscatter electron (BSE) image of experimental melt MS13. The shade of grey is an indication of average atomic number (Z); black areas indicate holes or cracks (no electron return) while white areas indicate a relatively high average Z.

Left: Energy dispersive X-ray spectrograph (EDS) map of MS13 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; melt, plagioclase, orthopyroxene, clinopyroxene, amphibole.

Fig. C9 Top: Backscatter electron (BSE) image of experimental melt MS15. The shade of grey is an indication of average atomic number (Z); black areas indicate holes or cracks (no electron return) while white areas indicate a relatively high average Z.

Left: Energy dispersive X-ray spectrograph (EDS) map of MS15 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; quartz, melt, orthopyroxene, FeTi oxides, pyrite.

Fig. C10 Top: Backscatter electron (BSE) image of experimental melt MS16. The shade of grey is an indication of average atomic number (Z); black areas indicate holes or cracks (no electron return) while white areas indicate a relatively high average Z.

Left: Energy dispersive X-ray spectrograph (EDS) map of MS16 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; melt, quartz, orthopyroxene, FeTi oxides.

Fig. C11 Top: Backscatter electron (BSE) image of experimental melt MS17. The shade of grey is an indication of average atomic number (Z); black areas indicate holes or cracks (no electron return) while white areas indicate a relatively high average Z.

Left: Energy dispersive X-ray spectrograph (EDS) map of MS17 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; melt, plagioclase, orthopyroxene, FeTi oxides, apatite, pyrite.

Fig. C12 Top: Backscatter electron (BSE) image of experimental melt MS18. The shade of grey is an indication of average atomic number (Z); black areas indicate holes or cracks (no electron return) while white areas indicate a relatively high average Z.

Left: Energy dispersive X-ray spectrograph (EDS) map of MS18 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; plagioclase, melt, quartz, orthopyroxene, amphibole, apatite.

Fig. C13 Top: Backscatter electron (BSE) image of experimental melt MS19. The shade of grey is an indication of average atomic number (Z); black areas indicate holes or cracks (no electron return) while white areas indicate a relatively high average Z.

Left: Energy dispersive X-ray spectrograph (EDS) map of MS19 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; clinopyroxene, melt, apatite, FeTi oxides.

Fig. C14 Top: Backscatter electron (BSE) image of experimental melt MS22. The shade of grey is an indication of average atomic number (Z); black areas indicate holes or cracks (no electron return) while white areas indicate a relatively high average Z.

Left: Energy dispersive X-ray spectrograph (EDS) map of MS22 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; melt, clinopyroxene, plagioclase, FeTi oxides.

Fig. C15 Top: Backscatter electron (BSE) image of experimental melt MS23. The shade of grey is an indication of average atomic number (Z); black areas indicate holes or cracks (no electron return) while white areas indicate a relatively high average Z.

Left: Energy dispersive X-ray spectrograph (EDS) map of MS23 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; plagioclase, biotite, melt, orthopyroxene, FeTi oxides, apatite.

Fig. C16 Top: Backscatter electron (BSE) image of experimental melt MS26. The shade of grey is an indication of average atomic number (Z); black areas indicate holes or cracks (no electron return) while white areas indicate a relatively high average Z.

Left: Energy dispersive X-ray spectrograph (EDS) map of MS26 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; melt, clinopyroxene, FeTi oxides, apatite.

Fig. C17 Top: Backscatter electron (BSE) image of experimental melt MS27. The shade of grey is an indication of average atomic number (Z); black areas indicate holes or cracks (no electron return) while white areas indicate a relatively high average Z.

Left: Energy dispersive X-ray spectrograph (EDS) map of MS27 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; melt, quartz, orthopyroxene, clinopyroxene, FeTi oxides, apatite.

Fig. C18 Top: Backscatter electron (BSE) image of experimental melt MS28. The shade of grey is an indication of average atomic number (Z); black areas indicate holes or cracks (no electron return) while white areas indicate a relatively high average Z.

Left: Energy dispersive X-ray spectrograph (EDS) map of MS28 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; melt, plagioclase, orthopyroxene, FeTi oxides, clinopyroxene, apatite.

Fig. C19 Top: Backscatter electron (BSE) image of experimental melt MS29. The shade of grey is an indication of average atomic number (Z); black areas indicate holes or cracks (no electron return) while white areas indicate a relatively high average Z.

Left: Energy dispersive X-ray spectrograph (EDS) map of MS29 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; melt, plagioclase, clinopyroxene, biotite, FeTi oxides, apatite.

Fig. C20 Top: Backscatter electron (BSE) image of experimental melt MS30. The shade of grey is an indication of average atomic number (Z); black areas indicate holes or cracks (no electron return) while white areas indicate a relatively high average Z.

Left: Energy dispersive X-ray spectrograph (EDS) map of MS30 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; melt, quartz, orthopyroxene, clinopyroxene, pyrite.

Fig. C21 Top: Backscatter electron (BSE) image of experimental melt MS33. The shade of grey is an indication of average atomic number (Z); black areas indicate holes or cracks (no electron return) while white areas indicate a relatively high average Z.

Left: Energy dispersive X-ray spectrograph (EDS) map of MS33 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; melt, clinopyroxene, amphibole, FeTi oxides.

Fig. C22 Top: Backscatter electron (BSE) image of experimental melt MS34. The shade of grey is an indication of average atomic number (Z); black areas indicate holes or cracks (no electron return) while white areas indicate a relatively high average Z.

Left: Energy dispersive X-ray spectrograph (EDS) map of MS34 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; melt, clinopyroxene, orthopyroxene, FeTi oxides.

Fig. C23 Top: Backscatter electron (BSE) image of experimental melt MS35. The shade of grey is an indication of average atomic number (Z); black areas indicate holes or cracks (no electron return) while white areas indicate a relatively high average Z .

Left: Energy dispersive X-ray spectrograph (EDS) map of MS35 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; melt, clinopyroxene, plagioclase, orthopyroxene.

Fig. C24 Top: Backscatter electron (BSE) image of experimental melt MS37. The shade of grey is an indication of average atomic number (Z); black areas indicate holes or cracks (no electron return) while white areas indicate a relatively high average Z.

Left: Energy dispersive X-ray spectrograph (EDS) map of MS37 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; melt, biotite, plagioclase, FeTi oxides, apatite.

Fig. C25 Top: Backscatter electron (BSE) image of experimental melt MS38. The shade of grey is an indication of average atomic number (Z); black areas indicate holes or cracks (no electron return) while white areas indicate a relatively high average Z.

Left: Energy dispersive X-ray spectrograph (EDS) map of MS38 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; melt, plagioclase, orthopyroxene, clinopyroxene, apatite, FeTi oxides.

Fig. C26 Top: Backscatter electron (BSE) image of experimental melt MS39. The shade of grey is an indication of average atomic number (Z); black areas indicate holes or cracks (no electron return) while white areas indicate a relatively high average Z.

Left: Energy dispersive X-ray spectrograph (EDS) map of MS39 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; melt, clinopyroxene, FeTi oxides.

Fig. C27 Top: Backscatter electron (BSE) image of experimental melt MS40. The shade of grey is an indication of average atomic number (Z); black areas indicate holes or cracks (no electron return) while white areas indicate a relatively high average Z.

Left: Energy dispersive X-ray spectrograph (EDS) map of MS40 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; clinopyroxene, plagioclase, melt, FeTi oxides, apatite.

Fig. C28 Top: Backscatter electron (BSE) image of experimental melt MS41. The shade of grey is an indication of average atomic number (Z); black areas indicate holes or cracks (no electron return) while white areas indicate a relatively high average Z.

Left: Energy dispersive X-ray spectrograph (EDS) map of MS41 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; clinopyroxene, plagioclase, melt, FeTi oxides, apatite.

Fig. C29 Top: Backscatter electron (BSE) image of experimental melt MS43. The shade of grey is an indication of average atomic number (Z); black areas indicate holes or cracks (no electron return) while white areas indicate a relatively high average Z.

Left: Energy dispersive X-ray spectrograph (EDS) map of MS43 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; melt, biotite, clinopyroxene, orthopyroxene, apatite, amphibole.

Fig. C30 Top: Backscatter electron (BSE) image of experimental melt MS44. The shade of grey is an indication of average atomic number (Z); black areas indicate holes or cracks (no electron return) while white areas indicate a relatively high average Z.

Left: Energy dispersive X-ray spectrograph (EDS) map of MS44 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; melt, clinopyroxene, amphibole, apatite.

Fig. C31 Top: Backscatter electron (BSE) image of experimental melt MS45. The shade of grey is an indication of average atomic number (Z); black areas indicate holes or cracks (no electron return) while white areas indicate a relatively high average Z.

Left: Energy dispersive X-ray spectrograph (EDS) map of MS45 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; quartz, melt, orthopyroxene, plagioclase, biotite, magnetite.

Fig. C32 Top: Backscatter electron (BSE) image of experimental melt MS46. The shade of grey is an indication of average atomic number (Z); black areas indicate holes or cracks (no electron return) while white areas indicate a relatively high average Z.

Left: Energy dispersive X-ray spectrograph (EDS) map of MS46 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; melt, biotite, plagioclase, FeTi oxides, orthopyroxene, clinopyroxene, apatite.

Fig. C33 Top: Backscatter electron (BSE) image of experimental melt MS47. The shade of grey is an indication of average atomic number (Z); black areas indicate holes or cracks (no electron return) while white areas indicate a relatively high average Z.

Left: Energy dispersive X-ray spectrograph (EDS) map of MS47 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; melt, clinopyroxene, quartz, amphibole, apatite.

Fig. C34 Top: Backscatter electron (BSE) image of experimental melt MS48. The shade of grey is an indication of average atomic number (Z); black areas indicate holes or cracks (no electron return) while white areas indicate a relatively high average Z.

Left: Energy dispersive X-ray spectrograph (EDS) map of MS48 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; melt, quartz, orthopyroxene, biotite, FeTi oxides.

Fig. C35 Top: Backscatter electron (BSE) image of experimental melt MS49. The shade of grey is an indication of average atomic number (Z); black areas indicate holes or cracks (no electron return) while white areas indicate a relatively high average Z.

Left: Energy dispersive X-ray spectrograph (EDS) map of MS49 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; melt, orthopyroxene, FeTi oxides.

Fig. C36 Top: Backscatter electron (BSE) image of experimental melt MS50. The shade of grey is an indication of average atomic number (Z); black areas indicate holes or cracks (no electron return) while white areas indicate a relatively high average Z.

Left: Energy dispersive X-ray spectrograph (EDS) map of MS50 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; melt, quartz, orthopyroxene, amphibole, pyrite.

Fig. C37 Top: Backscatter electron (BSE) image of experimental melt MS51. The shade of grey is an indication of average atomic number (Z); black areas indicate holes or cracks (no electron return) while white areas indicate a relatively high average Z.

Left: Energy dispersive X-ray spectrograph (EDS) map of MS51 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; melt, orthopyroxene, amphibole.

Fig. C38 Top: Backscatter electron (BSE) image of experimental melt MS52. The shade of grey is an indication of average atomic number (Z); black areas indicate holes or cracks (no electron return) while white areas indicate a relatively high average Z.

Left: Energy dispersive X-ray spectrograph (EDS) map of MS52 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; melt, orthopyroxene, plagioclase, clinopyroxene, pyrite.

Fig. C39 Top: Backscatter electron (BSE) image of experimental melt MS53. The shade of grey is an indication of average atomic number (Z); black areas indicate holes or cracks (no electron return) while white areas indicate a relatively high average Z.

Left: Energy dispersive X-ray spectrograph (EDS) map of MS53 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; melt, clinopyroxene, orthopyroxene, FeTi oxides.

Fig. C40 Top: Backscatter electron (BSE) image of experimental melt MS55. The shade of grey is an indication of average atomic number (Z); black areas indicate holes or cracks (no electron return) while white areas indicate a relatively high average Z.

Left: Energy dispersive X-ray spectrograph (EDS) map of MS55 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; melt, orthopyroxene, clinopyroxene, biotite, FeTi oxides.

Fig. C41 Top: Backscatter electron (BSE) image of experimental melt MS57. The shade of grey is an indication of average atomic number (Z); black areas indicate holes or cracks (no electron return) while white areas indicate a relatively high average Z.

Left: Energy dispersive X-ray spectrograph (EDS) map of MS57 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; melt, clinopyroxene, orthopyroxene, FeTi oxides.

Fig. C42 Top: Backscatter electron (BSE) image of experimental melt MS58. The shade of grey is an indication of average atomic number (Z); black areas indicate holes or cracks (no electron return) while white areas indicate a relatively high average Z.

Left: Energy dispersive X-ray spectrograph (EDS) map of MS58 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; melt, orthopyroxene, clinopyroxene.

Fig. C43 Top: Backscatter electron (BSE) image of experimental melt MS59. The shade of grey is an indication of average atomic number (Z); black areas indicate holes or cracks (no electron return) while white areas indicate a relatively high average Z.

Left: Energy dispersive X-ray spectrograph (EDS) map of MS59 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; melt, clinopyroxene, orthopyroxene.

Fig. C44 Top: Backscatter electron (BSE) image of experimental melt MS60. The shade of grey is an indication of average atomic number (Z); black areas indicate holes or cracks (no electron return) while white areas indicate a relatively high average Z.

Left: Energy dispersive X-ray spectrograph (EDS) map of MS60 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; quartz, melt, biotite, pyrite.

Fig. C45 Top: Backscatter electron (BSE) image of experimental melt MS62. The shade of grey is an indication of average atomic number (Z); black areas indicate holes or cracks (no electron return) while white areas indicate a relatively high average Z .

Left: Energy dispersive X-ray spectrograph (EDS) map of MS62 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; alkali feldspar, quartz, FeTi oxides, pyrite.

Fig. C46 Top: Backscatter electron (BSE) image of experimental melt MS63. The shade of grey is an indication of average atomic number (Z); black areas indicate holes or cracks (no electron return) while white areas indicate a relatively high average Z.

Left: Energy dispersive X-ray spectrograph (EDS) map of MS63 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; melt, quartz, orthopyroxene, amphibole, apatite.

Fig. C47 Top: Backscatter electron (BSE) image of experimental melt MS65. The shade of grey is an indication of average atomic number (Z); black areas indicate holes or cracks (no electron return) while white areas indicate a relatively high average Z.

Left: Energy dispersive X-ray spectrograph (EDS) map of MS65 created using the Oxford AZtec software. The order of phases in the key indicates the relative abundance of each phase; melt, quartz, plagioclase, orthopyroxene, amphibole, alkali feldspar, biotite, FeTi oxides, apatite.

Table C1: Experimental melt compositions, capsules, and melting conditions

Conditions	Capsule	Parent Material	Capsule Material	Fluid X _{H2O}	Mass relations in charges										
					H ₂ O wt%	H ₂ O mg	Ag ₂ C ₂ O ₄ mg	glass powder mg	capsule mg	capsule + H ₂ O	capsule + H ₂ O + glass + Ag ₂ C ₂ O ₄	capsule + H ₂ O + glass	the same after welding	the same after drying	after run
500MPa, 925°C, T-cycling, QFM+2	MS1	MS-12-47	Au	dry				39.55	567.78			607.33			
	MS2	TM13-3	Au	dry				39.46	450.03			489.76			
	MS3	TM13-5	Au	dry				39.93	499.47			539.40			
	MS4	MS-12-47	Au	<1	5.19	2.09		40.25	574.53	576.62		616.87		616.39	
	MS5	TM13-3	Au	<1	3.40	1.39		40.85	627.96	629.35		670.20		669.92	
	MS6	TM13-5	Au	<1	2.94	1.20		40.79	632.63	633.83		674.62		674.46	
500MPa, 875°C, T-cycling, QFM+2	MS15	MS-12-47	Au	dry	0	0		39.63	432.92	432.92		472.55	472.49		472.41
	MS16	TM13-3	Au	≈3%	3.13	1.2		38.28	579.52	580.72		619.00	618.93		618.81
	MS17	TM13-5	Au	dry	0	0		39.96	488.74	488.74		528.70	528.59		528.54
	MS18	MS-12-47	Au	≈3%	3.27	1.32		40.40	553.94	555.26		594.34	594.18		595.15
	MS19	TM13-3	Au	≈1%	1.06	0.42		39.44	573.23	573.65		613.09	612.40		612.33
	MS20	TM13-5	Au	≈4%	4.10	1.66		40.50	731.7	733.36		773.86	773.82		773.03
500MPa, 960°C, T-cycling, QFM+2	MS7	MS-12-47	Au	dry				40.20	559.67			592.44		592.29	614.94
	MS8	TM13-3	Au	dry				40.75	516.09			555.87		555.86	555.62
	MS9	TM13-5	Au	dry				40.45	519.67			559.01		522.86	522.70
	MS13	TM13-3	Au	≈3%	1.95	0.78		40.02	483.05	483.83		522.14	522.08	522.12	521.89
	MS22	TM13-5	Au	≈3%	2.95	1.20		40.68	549.98	552.51		589.10		589.12	588.86
	MS23	TM13-1	Au	dry				39.55	562.06			599.99		599.96	599.71

500MPa, 1000°C, T-cycling, QFM+2	MS24	*50M2A	Au	dry		7	40	519.77		526.23	566.90	520.93	520.87	517.76
	MS25	*50M2B	Au	dry		7	40	545.86		553.24	597.18	597.18	596.91	593.83
	MS26	*50M2C	Au	dry		7	40	520.02		527.23	566.67	533.43	533.37	532.92
	MS27	*50M3A	Au	dry		7	40	537.6		544.45	583.84	583.74	583.58	583.02
	MS28	*50M3B	Au	dry		7	40	534.85		541.38	583.89	583.9	583.89	583.05
	MS29	*50M3C	Au	dry		7	40	491.42		497.99	539.07	539.07	538.89	538.88
	MS30	*50M1A	Au	dry		7	40	529.86		536.20	576.20	562.69	562.68	561.19
	MS31	*50M1B	Au	dry		7	40	511.02		517.98	559.52	558.28	558.15	554.87
	MS32	*50M1C	Au	dry		7	40	513.90		520.88	562.38	546.39	546.31	543.87
	MS33	*50M1D	Au	dry		7	40	515.97		522.99	562.24	560.52	560.54	558.17
	MS34	*50M2D	Au	dry		7	40	538.36		545.63	586.31	586.11	586.17	585.63
	MS35	*50M3D	Au	dry		7	40	512.56		519.58	559.45	557.72	557.7	557.99
	MS36	TM13-1	Au	dry	0	-	40.48	528.31			569.90	568.95	568.86	568.13
	MS37	TM13-1	Au	~2%	0.8	-	40.51	537.49	538.38		577.38	577.22	577.09	577.00
	MS38	TM13-3	Au	~4%	1.6	-	40.22	639.26	640.94		680.45	680.36	680.34	684.45
	MS39	TM13-3	Au	~6%	2.4	-	40.58	621.09	623.62		663.91	663.66	663.64	663.47
	MS40	TM13-5	Au	~4%	1.6	-	40.15	563.54	565.17		604.28	604.14	604.06	603.91
	MS41	TM13-5	Au	~6%	2.4	-	40.52	505.1	507.51		547.24	547.05	547.02	546.92
	MS42	*50M2A	Au	dry		4.02	40.61	542.82		587.23		586.93	586.9	584.88
	MS43	*50M2B	Au	dry		4.09	40.41	526.58		570.16		569.45	569.44	569.35
	MS44	*50M2C	Au	dry		4.01	40.43	512.3		556.44		556.29	556.27	555.90
	MS45	*50M3A	Au	dry		4.01	40.46	532.27		576.67		576.41	576.37	576.18
	MS46	*50M3B	Au	dry		4.06	40.44	536.15		580.09		580.01	579.97	579.82
	MS47	*50M3C	Au	dry		4.22	40.54	527.03		570.99		570.88	570.84	570.62

500MPa, 1000°C, T- cycling, QFM+2, 7 days	MS48	*50M3A	Au	dry				40.46	545.33			585.79	581.49		581.22
	MS49	*50M3A	Au	2%		0.84		39.99	543.55	544.39		584.38	573.37	573.33	572.82
	MS50	*50M2A	Au	dry				40.14	560.07			600.21	582.65		582.22
	MS51	*50M2A	Au	2%		0.86		40.3	536.46	537.32		577.62	569.07	569.03	568.77
	MS52	*50M1A	Au	2%		0.81		39.84	549.71	550.52		590.36	575.00	574.95	574.61
	MS53	*50M1C	Au	dry				40.23	473.43			513.66	509.35		509.20
500MPa, 1040°C, T- cycling, QFM	MS54	*50M1A		dry			4.01	40.72	506.76		550.07		549.82	549.78	
	MS55	*50M1B		dry			4	40.06	511.44		554.24		553.93	553.92	
	MS56	*50M1C		dry			4.74	40.21	523.78		567.76		567.55	567.53	
	MS57	*50M1D		dry			4	40.22	528.04		572.02		571.76	571.75	
	MS58	*50M1A		0.02	2	0.8	-	40.28	521.4	522.24	561.22		561.18	561.19	
	MS59	*50M2C		2%	2	0.8	-	40.58	514.91	515.76	556.22		555.86	555.85	
500MPa, 960°C, T-cycling, QFM	MS60	MS-12-47		dry											
	MS61	TM13-1		dry											
	MS62	*50M2A		dry											
	MS63	*50M2A		1%											
	MS64	*50M1C		1%											
	MS65	*50MAB		dry											

*Notation of mixes: 1, 2, 3 = mafic glass:

A, B, C, D = protoliths:

1 = HAOT

A = mica fels; MS-12-47

50 = 50:50 mix

2 = FeAnd

B = biotite schist; TM13-1

M = mix

3 = IC

C = granodiorite; TM13-3

D = amphibolite; TM13-5

Table C2: Unnormalized phase proportions and phase compositions

MS1	melt: 78.7%			quartz: 16.9%			orthopyroxene: 4.5%			pyrite: 0.01%		
	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %
	O	64.61	49.74	O	66.56	52.90	O	62.20	45.42	O	66.64	42.24
	Al	5.01	6.50	Si	33.24	46.39	Na	0.43	0.45	Si	0.62	0.69
	Si	27.38	37.01	Fe	0.07	0.20	Mg	6.62	7.35	S	16.32	20.74
	K	1.66	3.13	Br	0.13	0.51	Al	2.95	3.63	Fe	16.42	36.33
	Ca	0.24	0.46				Si	19.85	25.44			
	Ti	0.16	0.37				S	1.70	2.48			
	Fe	0.89	2.39				K	0.68	1.21			
	Ba	0.06	0.40				Ca	0.16	0.29			
							Ti	0.18	0.40			
							V	0.04	0.09			
							Fe	5.20	13.24			
MS3	clinopyroxene: 76.9%			plagioclase: 14.6%			melt: 2.2%					
	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %			
	O	60.36	43.79	O	54.26	38.81	O	61.76	46.97			
	Na	1.49	1.55	Na	0.83	0.85	Na	2.30	2.51			
	Mg	5.16	5.69	Al	16.93	20.41	Al	8.70	11.16			
	Al	6.59	8.06	Si	19.42	24.38	Si	23.14	30.89			
	Si	17.93	22.84	Ca	8.28	14.83	K	0.34	0.63			
	K	0.11	0.20	Fe	0.29	0.73	Ca	2.83	5.40			
	Ca	4.45	8.09				Ti	0.12	0.27			
	Ti	0.30	0.64				Mn	0.13	0.33			
	Mn	0.08	0.19				Fe	0.70	1.85			
	Fe	3.53	8.94									
MS4	quartz: 41.9%			melt: 40.6%			plagioclase: 7.7%			orthopyroxene: 6.1%		
	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %
	O	66.26	52.21	O	63.27	48.28	O	62.18	47.65	O	61.52	43.95
	Si	32.99	45.63	Na	1.47	1.61	Na	0.34	0.37	Na	0.58	0.59
	K	0.32	0.61	Al	5.99	7.71	Mg	3.97	4.63	Mg	5.80	6.30
	Fe	0.13	0.35	Si	25.22	33.78	Al	12.12	15.67	Al	4.41	5.31
	Br	0.30	1.19	S	0.11	0.17	Si	18.73	25.19	Si	18.65	23.39
				K	2.57	4.79	K	0.65	1.21	S	1.09	1.56
				Ca	0.36	0.69	Ca	0.09	0.18	K	0.80	1.39

				Ti	0.13	0.29	Ti	0.06	0.14	Ca	0.18	0.31
				Fe	0.80	2.13	Mn	0.06	0.15	Ti	0.60	1.28
				Ba	0.08	0.55	Fe	1.80	4.81	V	0.06	0.13
										Mn	0.09	0.23
										Fe	6.24	15.55
				pyrite: 0.01%								
				element	atomic %	Wt %						
				O	64.15	38.42						
				Si	1.31	1.38						
				S	13.49	16.20						
				Fe	21.05	44.00						
MS5	melt: 70.1%			plagioclase: 17.5%			orthopyroxene: 7.6%			clinopyroxene: 1.6%		
	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %
	O	62.60	47.73	O	61.69	47.23	O	59.78	41.39	O	60.15	42.86
	Na	2.47	2.70	Na	3.10	3.41	Mg	10.31	10.85	Na	0.58	0.59
	Mg	0.59	0.69	Al	11.53	14.89	Si	20.73	25.20	Mg	6.71	7.27
	Al	6.65	8.54	Si	19.26	25.89	K	0.18	0.30	Al	2.10	2.52
	Si	23.55	31.53	K	0.19	0.36	Ca	0.98	1.71	Si	19.40	24.26
	K	1.26	2.34	Ca	4.05	7.77	Ti	0.14	0.28	K	0.15	0.27
	Ca	1.50	2.86	Fe	0.17	0.46	Mn	0.11	0.27	Ca	6.83	12.19
	Ti	0.19	0.44				Fe	6.55	15.82	Ti	0.22	0.48
	Fe	1.19	3.16				Br	1.21	4.19	Mn	0.09	0.23
										Fe	3.75	9.34
	FeTi oxides: 0.6%			apatite: 0.1%								
	element	atomic %	Wt %	element	atomic %	Wt %						
	O	59.57	32.41	O	60.83	41.22						
	Mg	2.44	2.02	Mg	0.48	0.50						
	Al	0.55	0.50	Al	1.63	1.86						
	Si	1.27	1.21	Si	5.64	6.71						
	Ca	0.15	0.20	P	10.24	13.44						
	Ti	17.60	28.66	K	0.33	0.54						
	Fe	18.43	35.00	Ca	20.35	34.55						
				Fe	0.50	1.17						
MS6	melt: 66.9%			plagioclase: 28.6%			orthopyroxene: 2.3%			apatite: 0.2%		
	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %

O	60.05	43.20	O	54.78	39.50	O	51.19	34.51	O	55.33	35.30
Na	1.37	1.41	Na	1.49	1.54	Mg	14.54	14.90	Mg	0.45	0.43
Mg	6.08	6.64	Mg	0.20	0.21	Al	1.76	2.00	Al	0.54	0.58
Al	5.83	7.07	Al	15.47	18.82	Si	23.32	27.60	Si	1.05	1.18
Si	17.58	22.21	Si	20.46	25.90	Ca	0.93	1.56	P	15.28	18.87
K	0.12	0.20	Ca	7.20	13.01	Ti	0.08	0.16	Cl	0.36	0.51
Ca	4.46	8.03	Fe	0.40	1.01	Mn	0.27	0.64	Ca	26.99	43.14
Ti	0.35	0.74				Fe	7.91	18.62			
Mn	0.09	0.22									
Fe	4.09	10.26									
FeTi oxides: 0.04%											
element	atomic %	Wt %									
O	53.75	27.72									
Mg	3.16	2.48									
Al	1.38	1.20									
Si	2.07	1.88									
Ca	0.70	0.90									
Ti	16.56	25.56									
Fe	22.37	40.26									

MS8	melt: 85.3%			orthopyroxene: 12.1%			clinopyroxene: 1.3%			apatite: 0.3%		
	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %
	O	60.96	46.22	O	58.23	40.93	O	59.45	42.30	O	62.22	43.77
	Na	2.86	3.12	Na	1.00	1.01	Na	1.00	1.02	Na	1.09	1.10
	Mg	0.59	0.67	Mg	7.28	7.78	Mg	5.15	5.57	Mg	0.28	0.30
	Al	8.16	10.44	Al	3.38	4.01	Al	3.06	3.68	Al	2.96	3.52
	Si	23.21	30.90	Si	21.36	26.36	Si	20.04	25.03	Si	8.04	9.93
	K	1.00	1.85	K	0.45	0.77	P	0.72	1.00	P	8.98	12.23
	Ca	2.22	4.21	Ca	1.45	2.55	K	0.42	0.74	Cl	0.28	0.43
	Ti	0.14	0.31	Ti	0.61	1.29	Ca	6.36	11.34	K	0.35	0.60
	Fe	0.87	2.29	V	0.01	0.02	Ti	0.22	0.46	Ca	15.38	27.09
				Mn	0.12	0.29	Fe	3.57	8.86	Fe	0.42	1.03
				Fe	6.11	15.00						
	zircon: 0.4%			amphibole: 0.1%								
	element	atomic %	Wt %	element	atomic %	Wt %						
	O	63.41	37.78	O	61.22	38.35						
	Na	1.43	1.22	Na	1.33	1.19						
	Mg	0.84	0.76	Mg	1.73	1.65						

	Al	2.28	2.29	Al	2.86	3.02						
	Si	19.55	20.45	Si	11.31	12.43						
	K	0.75	1.09	K	0.64	0.99						
	Ca	1.47	2.19	Ca	0.58	0.91						
	Fe	0.53	1.11	Ti	9.61	18.02						
	Zr	9.75	33.12	Fe	10.72	23.44						
MS9	melt: 50.3%			clinopyroxene: 42.6%			orthopyroxene: 4.5%			FeTi oxides: 1.6%		
	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %
	O	60.75	44.90	O	60.00	43.00	O	58.92	42.34	O	53.33	27.11
	Na	1.48	1.58	Na	1.00	1.00	Mg	15.20	16.59	Mg	2.77	2.14
	Mg	4.21	4.72	Mg	5.54	5.62	Al	1.51	1.83	Al	5.00	4.29
	Al	8.58	10.70	Al	3.10	3.82	Si	16.90	21.31	Si	1.92	1.71
	Si	17.81	23.11	Si	20.04	25.03	Ca	1.00	1.80	Ca	0.60	0.76
	K	0.08	0.14	Ca	6.70	12.53	Ti	0.19	0.42	Ti	2.24	3.41
	Ca	4.63	8.57	Fe	3.62	9.00	Mn	0.85	2.11	Fe	34.13	60.57
	Ti	0.19	0.41				Fe	5.42	13.60			
	Mn	0.05	0.11									
	Fe	2.23	5.75									
	apatite: 0.02%											
	element	atomic %	Wt %									
	O	59.52	38.95									
	Si	2.34	2.68									
	P	11.14	14.11									
	Ca	27.00	44.25									
MS13	melt: 73.3%			plagioclase: 15.0%			orthopyroxene: 9.4%			clinopyroxene: 1.0%		
	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %
	O	62.46	47.52	O	59.59	45.07	O	59.27	42.93	O	59.37	40.78
	Na	2.58	2.82	Na	3.44	3.74	Na	1.07	1.11	Na	0.50	0.49
	Mg	0.67	0.78	Al	12.26	15.64	Mg	8.11	8.93	Mg	7.23	7.55
	Al	6.81	8.74	Si	20.08	26.67	Al	3.32	4.06	Si	20.13	24.28
	Si	23.15	30.93	K	0.17	0.32	Si	21.59	27.45	K	0.15	0.26
	K	1.17	2.17	Ca	4.27	8.09	K	0.47	0.84	Ca	7.30	12.55
	Ca	1.68	3.19	Fe	0.18	0.48	Ca	1.17	2.11	Ti	0.23	0.47
	Ti	0.21	0.49				Ti	0.16	0.36	Fe	3.71	8.89
	Fe	1.27	3.37				Mn	0.10	0.24	Br	1.38	4.73

MS16	melt: 62.9%			quartz: 26.4%			orthopyroxene: 2.3%			FeTi oxides: 1.5%		
	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %
	O	63.52	48.75	O	66.52	52.03	O	60.10	43.02	O	57.73	35.21
	Na	1.07	1.18	Si	32.86	45.12	Mg	11.08	12.05	Na	0.60	0.53
	Mg	0.96	1.12	K	0.15	0.28	Al	2.97	3.58	Mg	0.78	0.73
	Al	5.61	7.27	Fe	0.06	0.16	Si	18.60	23.38	Al	2.33	2.40
	Si	25.59	34.48	Y	0.31	1.33	K	0.10	0.17	Si	11.56	12.38
	K	1.88	3.53				Ti	0.17	0.36	S	5.34	6.52
	Ca	0.26	0.50				Mn	0.11	0.28	K	0.62	0.92
	Ti	0.12	0.27				Fe	6.87	17.15	Ca	0.10	0.15
	Fe	0.92	2.45							Ti	11.15	20.37
	Ba	0.07	0.46							V	0.20	0.39
										Fe	9.59	20.42

MS17	melt: 55.2%			plagioclase: 38.3%			orthopyroxene: 5.3%			FeTi oxides: 0.4%		
	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %
	O	58.95	40.77	O	61.77	46.95	O	60.35	41.89	O	53.64	26.87
	Na	0.62	0.61	Na	2.87	3.13	Mg	7.68	8.10	Mg	1.32	1.00
	Mg	5.95	6.25	Al	10.27	13.16	Al	2.62	3.06	Al	3.98	3.36
	Al	7.40	8.63	Si	20.32	27.11	Si	19.54	23.81	Si	2.53	2.22
	Si	15.76	19.13	K	0.96	1.79	K	0.39	0.67	S	0.50	0.50
	K	4.10	6.93	Ca	3.10	5.89	Ca	0.46	0.81	Ti	1.78	2.66
	Ca	0.23	0.40	Fe	0.71	1.88	Ti	0.06	0.13	Fe	36.26	63.39
	Ti	0.71	1.47	Tb	0.01	0.08	Mn	0.34	0.82			
	V	0.05	0.11				Fe	8.55	20.71			
	Fe	6.04	14.59									
	In	0.06	0.27									
	Ba	0.14	0.83									

apatite: 0.2%			pyrite: 0.04%		
element	atomic %	Wt %	element	atomic %	Wt %
O	60.69	41.19	O	66.82	41.95
Na	0.55	0.53	S	16.68	20.99
Mg	0.94	0.97	Fe	16.32	35.77
Al	2.11	2.41	Ta	0.18	1.29
Si	5.71	6.80			
P	10.29	13.51			
K	1.06	1.77			

	Ca	17.03	28.95									
	Fe	1.63	3.87									
MS18	plagioclase: 42.7%			melt: 20.2%			quartz: 4.0%			orthopyroxene: 5.6%		
	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %
	O	61.83	47.47	O	62.17	46.46	O	66.40	52.10	O	60.27	42.59
	Na	3.55	3.91	Na	1.53	1.64	Si	32.89	45.29	Na	0.60	0.61
	Al	9.89	12.80	Mg	2.44	2.77	K	0.12	0.24	Mg	8.05	8.64
	Si	20.85	28.10	Al	4.64	5.85	Ca	0.14	0.27	Al	1.74	2.07
	K	0.70	1.32	Si	23.55	30.89	Fe	0.14	0.39	Si	19.96	24.76
	Ca	2.83	5.45	Ar	0.10	0.18	Br	0.14	0.53	K	0.40	0.68
	Fe	0.35	0.94	K	1.75	3.20	Sb	0.10	0.58	Ca	2.09	3.70
				Ca	1.22	2.28	Te	0.05	0.28	Ti	0.17	0.35
				Ti	0.21	0.46				V	0.03	0.07
				Fe	2.40	6.26				Mn	0.14	0.35
										Fe	6.55	16.17
	amphibole: 1.2%			apatite: 0.4%								
	element	atomic %	Wt %	element	atomic %	Wt %						
	O	61.35	41.25	O	58.96	40.52						
	Na	1.68	1.63	Na	1.23	0.53						
	Mg	1.73	1.77	Mg	0.78	0.97						
	Al	4.20	4.76	Al	2.07	2.41						
	Si	16.13	19.03	Si	7.83	6.80						
	K	1.08	1.77	P	6.92	13.51						
	Ca	1.05	1.77	Cl	0.36	0.67						
	Ti	5.86	11.80	K	0.68	1.77						
	Fe	6.91	16.23	Ca	20.57	28.95						
				Fe	0.59	3.87						
MS19	clinopyroxene: 68.2%			melt: 27.8%			apatite: 0.3%			FeTi oxides: 0.1%		
	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %
	O	59.98	43.16	O	61.60	46.37	O	60.18	41.17	O	58.95	35.71
	Na	1.42	1.47	Na	1.46	1.58	Na	0.82	0.81	Na	1.05	0.91
	Mg	6.18	6.76	Al	13.26	16.84	Mg	1.80	1.87	Mg	4.61	4.25
	Al	5.99	7.27	Si	17.31	22.87	Al	2.84	3.28	Al	3.02	3.09
	Si	17.37	21.95	Ca	5.94	11.20	Si	6.92	8.31	Si	7.94	8.45
	K	0.11	0.19	Fe	0.41	1.08	P	8.39	11.11	Ca	2.25	3.42

	Ca	4.43	7.98	Tb	0.01	0.06	Cl	0.15	0.23	Ti	8.98	16.28
	Ti	0.33	0.71				Ca	17.68	30.31	Fe	13.19	27.89
	V	0.02	0.05				Fe	1.22	2.91			
	Mn	0.10	0.24									
	Fe	4.08	10.25									
MS22	melt: 47.7%			clinopyroxene: 40.0%			plagioclase: 5.8%			FeTi oxides: 0.7%		
	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %
	O	63.61	47.80	O	58.56	42.17	O	59.59	44.01	O	53.67	27.49
	Na	1.51	1.63	Na	1.41	1.46	Na	0.52	0.55	Mg	3.57	2.78
	Mg	2.39	2.73	Mg	8.24	9.02	Al	15.50	19.31	Al	6.00	5.18
	Al	8.11	10.28	Al	6.32	7.68	Si	16.58	21.50	Si	0.80	0.72
	Si	17.96	23.70	Si	16.19	20.46	Ca	7.54	13.96	Ca	0.23	0.29
	K	0.11	0.21	K	0.08	0.13	Fe	0.26	0.67	Ti	1.29	1.97
	Ca	3.83	7.21	Ca	5.49	9.91				V	0.21	0.34
	Ti	0.17	0.39	Ti	0.36	0.78				Fe	34.19	61.13
	Mn	0.08	0.20	Fe	3.34	8.38				Co	0.06	0.10
	Fe	2.23	5.86									
MS23	plagioclase: 21.8%			biotite: 30.6%			melt: 33.3%			orthopyroxene: 10.2%		
	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %
	O	60.00	45.15	O	57.23	39.47	O	60.13	44.11	O	58.36	40.79
	Na	2.69	2.91	Na	0.53	0.53	Na	1.90	2.01	Mg	9.33	9.91
	Al	12.15	15.41	Mg	7.70	8.07	Mg	1.70	1.90	Al	3.35	3.95
	Si	19.80	26.15	Al	7.76	9.02	Al	7.62	9.43	Si	20.16	24.74
	K	0.73	1.35	Si	15.53	18.80	Si	21.88	28.17	K	0.55	0.95
	Ca	4.24	8.00	Cl	0.04	0.06	K	3.15	5.64	Ca	0.55	0.96
	Fe	0.39	1.04	K	4.50	7.58	Ca	0.93	1.70	Ti	0.09	0.20
				Ca	0.15	0.26	Ti	0.20	0.44	Mn	0.27	0.65
				Ti	0.89	1.83	V	0.02	0.05	Fe	7.32	17.85
				V	0.05	0.11	Mn	0.05	0.13			
				Fe	5.41	13.04	Fe	2.35	6.02			
				In	0.05	0.25	Ba	0.06	0.39			
				Ba	0.17	0.99						
	FeTi oxides: 3.2%			apatite: 0.4%								
	element	atomic %	Wt %	element	atomic %	Wt %						
	O	54.25	28.82	O	61.48	41.14						

	Mg	2.11	1.70	Si	0.63	0.74						
	Al	6.14	5.50	P	14.16	18.34						
	Si	4.86	4.53	Ca	23.74	39.79						
	S	0.27	0.29									
	K	0.65	0.85									
	Ca	0.19	0.26									
	Ti	1.40	2.22									
	V	0.17	0.28									
	Fe	29.96	55.55									
MS26	melt: 73.7%			clinopyroxene: 17.0%			FeTi oxides: 3.9%			apatite: 0.1%		
	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %
	O	62.12	47.23	O	60.62	42.91	O	37.58	57.14	O	61.73	42.13
	Na	2.92	3.19	Na	0.90	0.92	Na	1.93	2.04	Al	1.45	1.67
	Mg	0.44	0.51	Mg	5.70	6.14	Mg	1.30	1.30	Si	5.13	6.14
	Al	7.86	10.08	Al	2.53	3.02	Al	5.34	4.82	P	11.74	15.51
	Si	22.09	29.48	Si	20.36	25.30	Si	22.37	19.38	Ca	19.33	33.05
	K	1.09	2.02	K	0.46	0.80	P	0.25	0.19	Fe	0.63	1.49
	Ca	2.24	4.27	Ca	3.25	5.76	K	1.94	1.21			
	Ti	0.22	0.49	Ti	0.29	0.62	Ca	2.25	1.37			
	Fe	1.02	2.72	Mn	0.15	0.35	Ti	10.69	5.43			
				Fe	5.74	14.19	Fe	16.35	7.12			
MS27	melt: 55.0%			quartz: 13.0%			orthopyroxene: 6.5%			clinopyroxene: 0.8%		
	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %
	O	62.79	47.55	O	66.38	51.77	O	61.05	41.96	O	61.55	46.93
	Na	2.1	2.28	Al	0.47	0.62	Na	1	0.99	Na	3.31	3.63
	Mg	0.51	0.59	Si	32.4	44.35	Mg	3.24	3.39	Mg	0.34	0.39
	Al	5.78	7.38	K	0.18	0.34	Al	3.18	3.69	Al	10.61	13.64
	Si	24.32	32.33	Ca	0.1	0.2	Si	20.43	24.66	Si	19.77	26.46
	K	1.55	2.88	Fe	0.25	0.68	K	0.79	1.33	K	0.81	1.51
	Ca	1.19	2.26	Os	0.14	1.33	Ca	0.86	1.48	Ca	2.83	5.41
	Ti	0.19	0.44	Pt	0.07	0.71	Ti	0.96	1.98	Ti	0.1	0.23
	Fe	1.52	4.02				Mn	0.18	0.42	Fe	0.67	1.79
	Ba	0.04	0.28				Fe	8.26	19.82			
							Ba	0.05	0.29			
	FeTi oxides: 0.04%			apatite: 0.02%								

element	atomic %	Wt %	element	atomic %	Wt %
O	59.98	32.37	O	61.5	41.74
Mg	1.37	1.13	Al	1.32	1.51
Si	1.38	1.31	Si	5.52	6.58
Ti	18.59	30.03	P	11.44	15.03
Fe	18.67	35.17	K	0.67	1.1
			Ca	18.39	31.27
			Fe	1.17	2.77
MS28	melt: 60.7%		plagioclase: 12.1%		orthopyroxene: 11.1%
					FeTi oxides: 2.1%
element	atomic %	Wt %	element	atomic %	Wt %
O	61.40	45.02	O	61.50	46.93
Na	2.20	2.32	Na	3.28	3.59
Mg	1.10	1.22	Al	11.21	14.43
Al	7.06	8.73	Si	19.41	26.00
Si	21.33	27.46	K	0.73	1.36
K	2.67	4.79	Ca	3.49	6.68
Ca	1.25	2.31	Fe	0.38	1.01
Ti	0.30	0.66			
Fe	2.56	6.57			
Ba	0.06	0.36			
Ir	0.06	0.56			
clinopyroxene: 1.7%			apatite: 0.1%		
element	atomic %	Wt %	element	atomic %	Wt %
O	60.39	42.95	O	59.01	39.83
Na	0.91	0.93	F	3.41	2.73
Mg	5.02	5.42	Al	0.52	0.59
Al	3.25	3.90	Si	1.6	1.89
Si	18.64	23.28	P	13.04	17.04
P	0.77	1.06	Ca	22.43	37.92
K	0.79	1.38			
Ca	6.08	10.84			
Ti	0.20	0.43			
Fe	3.95	9.81			
MS29	melt: 62.0%		plagioclase: 17.7%		clinopyroxene: 10.5%
					FeTi oxides: 1.0%

	element atomic % Wt %		
	element	atomic %	Wt %
	O	66.77	42.46
	Si	0.60	0.67
	S	16.47	20.99
	Fe	16.16	35.88

MS33	melt: 55.9%			clinopyroxene: 25.4%			amphibole: 8.8%			FeTi oxides: 0.5%		
	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %
	O	61.27	45.90	O	59.91	42.79	O	57.53	39.97	O	54.82	28.71
	Na	2.61	2.82	Na	0.58	0.60	Mg	17.57	18.55	Mg	3.31	2.63
	Mg	0.62	0.71	Mg	7.07	7.68	Al	0.85	1.00	Al	5.37	4.74
	Al	11.16	14.10	Al	3.38	4.07	Si	14.56	17.76	Si	1.48	1.36
	Si	18.16	23.89	Si	18.07	22.66	Ca	0.39	0.68	Ca	0.28	0.36
	K	0.20	0.36	Ca	7.20	12.88	Ti	0.07	0.15	Ti	4.65	7.28
	Ca	4.49	8.44	Ti	0.35	0.74	Mn	0.16	0.37	V	0.40	0.67
	Ti	0.20	0.45	Mn	0.10	0.25	Fe	8.87	21.51	Cr	0.43	0.74
	Fe	1.28	3.34	Fe	3.34	8.32				Fe	29.27	53.50

MS34	melt: 63.6%			clinopyroxene: 20.6%			orthopyroxene: 5.2%			FeTi oxides: 0.5%		
	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %
	O	61.38	42.67	O	60.04	42.67	O	59.88	42.86	O	59.33	32.20
	Na	2.67	0.55	Na	0.54	0.55	Mg	12.12	13.19	Mg	3.12	2.57
	Mg	0.76	8.27	Mg	7.66	8.27	Al	1.50	1.81	Al	0.51	0.47
	Al	9.44	3.19	Al	2.66	3.19	Si	18.82	23.65	Si	0.60	0.58
	Si	19.31	23.34	Si	18.71	23.34	Ca	0.89	1.60	Ca	0.17	0.23
	K	0.71	0.20	K	0.12	0.20	Ti	0.18	0.39	Ti	17.46	28.37
	Ca	3.45	9.16	Ca	5.14	9.16	Mn	0.13	0.33	V	0.23	0.40
	Ti	0.37	0.78	Ti	0.37	0.78	Fe	6.47	16.16	Fe	18.57	35.18
	Fe	1.85	0.28	Mn	0.12	0.28						
	Ir	0.06	11.55	Fe	4.66	11.55						

MS35	melt: 66.5%			clinopyroxene: 15.3%			plagioclase: 10.7%			orthopyroxene: 2.6%		
	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %
	O	61.43	44.97	O	60.13	42.36	O	61.43	46.56	O	59.84	42.37
	Na	2.55	2.68	Mg	7.76	8.31	Na	2.39	2.60	Mg	11.57	12.45
	Mg	0.97	1.08	Al	2.15	2.55	Al	12.93	16.53	Al	1.22	1.46

	Al	7.64	9.43	Si	18.96	23.45	Si	17.68	23.52	Si	18.94	23.55
	Si	20.30	26.08	K	0.10	0.17	K	0.16	0.31	Ca	0.87	1.54
	K	0.99	1.77	Ca	5.08	8.96	Ca	5.11	9.71	Ti	0.12	0.25
	Ca	2.71	4.97	Ti	0.28	0.59	Fe	0.29	0.78	Mn	0.16	0.38
	Ti	0.44	0.97	Mn	0.16	0.40				Fe	7.28	17.99
	Mn	0.06	0.15	Fe	5.38	13.22						
	Fe	2.83	7.22									
	Ir	0.08	0.68									
MS37	melt: 50.9%			biotite: 34.8%			plagioclase: 9.3%			FeTi oxides: 4.1%		
	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %
	O	61.96	46.63	O	58.60	41.56	O	61.56	46.50	O	53.16	26.69
	Na	2.12	2.30	Na	0.59	0.61	Na	1.72	1.86	Mg	2.00	1.53
	Mg	1.16	1.32	Mg	8.73	9.41	Al	13.11	16.70	Al	4.41	3.73
	Al	7.33	9.31	Al	7.53	9.01	Si	17.56	23.28	Si	2.55	2.25
	Si	22.24	29.38	Si	15.04	18.73	K	0.26	0.49	K	0.26	0.32
	K	2.14	3.94	K	4.21	7.30	Ca	5.50	10.41	Ca	0.16	0.20
	Ca	1.32	2.48	Ca	0.16	0.29	Fe	0.29	0.77	Ti	1.44	2.17
	Ti	0.13	0.30	Ti	0.70	1.49				V	0.17	0.26
	V	0.01	0.03	V	0.04	0.09				Mn	0.33	0.57
	Mn	0.07	0.17	Mn	0.06	0.15				Fe	35.53	62.28
	Fe	1.47	3.87	Fe	4.13	10.23						
	Ba	0.04	0.27	In	0.04	0.23						
				Ba	0.15	0.91						
	apatite: 0.02%											
	element	atomic %	Wt %									
	O	60.77	40.31									
	Si	0.39	0.46									
	P	14.09	18.10									
	Ca	24.75	41.13									
MS38	melt: 47.7%			plagioclase: 28.0%			orthopyroxene: 6.7%			clinopyroxene: 3.2%		
	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %
	O	63.47	48.71	O	60.38	45.98	O	59.11	42.13	O	60.38	43.36
	Na	2.30	2.53	Na	3.62	3.96	Na	0.71	0.73	Na	0.89	0.91
	Mg	0.56	0.66	Al	11.02	14.16	Mg	9.14	9.90	Mg	6.02	6.57
	Al	5.81	7.53	Si	20.91	27.96	Al	2.41	2.90	Al	2.74	3.32
	Si	24.07	32.44	K	0.33	0.62	Si	20.93	26.19	Si	19.81	24.97

	Ar	0.10	0.19	Ca	3.47	6.62	K	0.35	0.60	K	0.29	0.51
	K	1.50	2.82	Fe	0.26	0.69	Ca	0.95	1.70	Ca	6.13	11.02
	Ca	1.02	1.96				Ti	0.17	0.36	Ti	0.17	0.36
	Ti	0.15	0.33				Mn	0.14	0.35	Mn	0.09	0.22
	Fe	0.99	2.64				Fe	6.09	15.15	Fe	3.50	8.76
	Ba	0.03	0.19									
	apatite: 0.3%			FeTi oxides: 0.6%								
	element	atomic %	Wt %	element	atomic %	Wt %						
	O	61.67	44.05	O	57.71	31.77						
	Na	1.42	1.46	Na	0.94	0.75						
	Mg	0.40	0.44	Mg	1.35	1.13						
	Al	3.52	4.24	Al	2.18	2.03						
	Si	12.87	16.14	Si	5.86	5.67						
	P	6.45	8.92	K	0.31	0.42						
	S	0.11	0.16	Ca	0.30	0.42						
	Cl	0.11	0.18	Ti	8.62	14.21						
	K	0.72	1.25	V	0.31	0.55						
	Ca	12.15	21.75	Fe	22.41	43.07						
	Fe	0.57	1.42									
MS39	melt: 93.7%			clinopyroxene: 5.5%			FeTi oxides: 0.2%					
	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %			
	O	62.42	47.58	O	59.48	42.80	O	52.39	25.47			
	Na	2.55	2.79	Na	1.43	1.48	Mg	2.31	1.71			
	Mg	0.79	0.91	Mg	7.96	8.70	Al	3.46	2.84			
	Al	7.29	9.37	Al	5.27	6.39	Si	0.47	0.40			
	Si	22.79	30.50	Si	16.64	21.01	Ti	2.59	3.77			
	K	0.96	1.78	K	0.26	0.45	Fe	38.78	65.81			
	Ca	1.88	3.59	Ca	4.48	8.08						
	Ti	0.15	0.34	Ti	0.54	1.16						
	Fe	1.17	3.12	Fe	3.95	9.93						
MS40	clinopyroxene: 46.4%			plagioclase: 15.1%			melt: 25.4%			FeTi oxides: 0.8%		
	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %
	O	59.61	42.94	O	59.86	44.38	O	64.36	49.37	O	53.74	26.49
	Na	1.36	1.40	Na	0.75	0.80	Na	2.06	2.28	Mg	2.33	1.74
	Mg	7.40	8.10	Al	15.16	18.96	Mg	0.88	1.03	Al	3.42	2.84
	Al	5.73	6.96	Si	16.78	21.83	Al	7.69	9.94	Si	0.35	0.30

	P	10.53	14.03									
	Ca	20.95	36.11									
	Fe	0.43	1.03									
MS43	melt: 54.1%			biotite: 22.2%			amphibole: 7.9%			clinopyroxene: 7.4%		
	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %
	O	61.59	46.38	O	59.29	41.57	O	46.76	25.90	O	60.31	43.11
	Na	2.55	2.75	Na	0.73	0.74	Na	1.79	1.43	Na	0.75	0.77
	Mg	0.87	1.00	Mg	6.99	7.45	Mg	2.78	2.34	Mg	7.03	7.64
	Al	8.44	10.72	Al	6.50	7.68	Al	6.82	6.37	Al	2.89	3.48
	Si	20.99	27.75	Si	16.30	20.07	Si	14.86	14.45	Si	19.61	24.61
	K	1.95	3.59	K	3.30	5.65	P	0.39	0.42	K	0.60	1.05
	Ca	2.18	4.11	Ca	0.51	0.89	K	1.39	1.88	Ca	3.63	6.50
	Ti	0.21	0.47	Ti	0.95	2.00	Ca	1.60	2.23	Ti	0.23	0.50
	Fe	1.22	3.22	V	0.05	0.10	Ti	2.79	4.63	Mn	0.17	0.42
				Fe	5.18	12.68	V	0.11	0.20	Fe	4.77	11.91
				In	0.05	0.24	Fe	20.64	39.91			0.24
				Ba	0.15	0.92	In	0.06	0.25			0.92
	orthopyroxene: 1.2%			apatite: 0.2%								
	element	atomic %	Wt %	element	atomic %	Wt %						
	O	59.69	42.23	O	60.85	40.82						
	Mg	11.76	12.64	Mg	0.39	0.40						
	Al	1.62	1.93	Al	0.90	1.01						
	Si	18.46	22.93	Si	2.53	2.99						
	K	0.20	0.34	P	12.74	16.54						
	Ca	0.61	1.08	Cl	0.25	0.37						
	Ti	0.20	0.43	K	0.26	0.43						
	Mn	0.25	0.61	Ca	21.56	36.24						
	Fe	7.21	17.82	Fe	0.52	1.21						
MS44	melt: 76.3%			clinopyroxene: 16.7%			amphibole: 2.3%			apatite: 0.23%		
	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %
	O	62.06	47.03	O	60.76	43.27	O	60.88	40.78	O	60.03	40.24
	Na	2.87	3.13	Na	1.12	1.14	Na	1.85	1.78	Na	0.61	0.59
	Mg	0.69	0.79	Mg	5.31	5.75	Mg	1.38	1.41	Mg	0.36	0.36
	Al	7.56	9.66	Al	3.12	3.74	Al	4.59	5.18	Al	1.24	1.41
	Si	22.03	29.31	Si	20.38	25.48	Si	16.68	19.61	Si	4.62	5.43

	K	1.05	1.95	K	0.56	0.97	P	0.12	0.16	P	10.34	13.42
	Ca	2.24	4.25	Ca	2.80	4.99	K	0.90	1.47	Cl	0.21	0.31
	Ti	0.27	0.62	Ti	0.42	0.90	Ca	1.35	2.27	K	0.37	0.60
	Fe	1.23	3.25	Mn	0.13	0.32	Ti	3.98	7.97	Ca	21.75	36.52
				Fe	5.41	13.44	Fe	8.28	19.36	Fe	0.47	1.11
MS45	quartz: 22.4%			melt: 54.8%			orthopyroxene: 11.9%			plagioclase: 3.0%		
	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %
	O	66.28	52.53	O	62.26	46.59	O	60.83	42.23	O	61.26	46.25
	Al	0.60	0.80	Na	2.40	2.58	Na	1.22	1.22	Na	2.62	2.84
	Si	32.43	45.12	Mg	0.52	0.59	Mg	3.60	3.79	Mg	1.03	1.18
	K	0.34	0.66	Al	6.73	8.49	Al	3.85	4.51	Al	12.06	15.36
	Ca	0.11	0.23	Si	22.92	30.11	Si	19.87	24.22	Si	18.05	23.92
	Fe	0.24	0.66	K	1.71	3.13	P	0.11	0.15	K	0.52	0.95
				Ca	1.46	2.73	K	0.91	1.54	Ca	3.07	5.81
				Ti	0.22	0.49	Ca	0.98	1.71	Fe	1.40	3.68
				Fe	1.67	4.37	Ti	0.76	1.59			
				Ba	0.05	0.31	Mn	0.17	0.41			
				Ir	0.07	0.60	Fe	7.69	18.63			
	biotite: 1.1%			FeTi oxides: 0.2%								
	element	atomic %	Wt %	element	atomic %	Wt %						
	O	58.29	42.17	O	58.04	31.51						
	Na	5.67	5.89	Mg	1.25	1.03						
	Mg	2.78	3.05	Al	1.90	1.74						
	Al	3.28	4.00	Si	4.98	4.75						
	Si	19.90	25.27	K	0.34	0.45						
	S	0.60	0.87	Ca	0.28	0.38						
	Cl	2.47	3.97	Ti	10.32	16.78						
	K	2.94	5.21	Fe	22.89	43.37						
	Ca	1.57	2.85									
	Ti	0.30	0.66									
	Fe	1.88	4.75									
	Zr	0.32	1.31									
MS46	melt: 60.5%			biotite: 19.7%			plagioclase: 6.9%			FeTi oxides: 5.6%		
	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %
	O	61.74	46.23	O	60.03	42.37	O	61.41	47.00	O	44.97	23.78

			element	atomic %	Wt %									
			O	59.91	39.21									
			P	13.22	16.75									
			Ca	26.87	44.05									
MS48	melt: 67.1%			quartz: 16.6%			orthopyroxene: 10.9%			biotite: 0.7%				
			element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %
			O	62.68	47.21	O	66.36	52.43	O	60.95	41.69	O	61.99	45.57
			Na	2.12	2.29	Si	33.05	45.84	Na	0.85	0.83	Na	1.88	1.99
			Mg	0.32	0.37	K	0.19	0.37	Mg	3.97	4.13	Mg	0.93	1.04
			Al	6.28	7.98	Fe	0.16	0.45	Al	2.64	3.05	Al	5.02	6.23
			Si	23.91	31.62	Br	0.23	0.92	Si	19.54	23.47	Si	20.15	26.01
			K	1.69	3.12				P	0.11	0.15	P	1.76	2.51
			Ca	1.30	2.46				S	0.26	0.36	S	0.09	0.14
			Ti	0.15	0.33				K	0.64	1.08	K	1.15	2.07
			Fe	1.44	3.79				Ca	1.06	1.81	Ca	4.90	9.02
			Ba	0.05	0.31				Ti	1.10	2.25	Fe	2.12	5.44
			Ir	0.06	0.52				Mn	0.20	0.46			
									Fe	8.68	20.73			
			FeTi oxides: 0.2%											
			element	atomic %	Wt %									
			O	59.37	31.94									
			Mg	1.00	0.82									
			Al	0.87	0.79									
			Si	2.09	1.97									
			S	0.26	0.28									
			Ti	15.69	25.27									
			Fe	20.73	38.93									
MS49	melt: 91.9%			orthopyroxene: 6.3%			FeTi oxides: 0.4%							
			element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %			
			O	51.73	36.48	O	59.69	40.84	O	59.46	34.44			
			Na	2.08	2.1	Mg	10.01	10.41	Na	0.98	0.82			
			Mg	0.67	0.71	Al	0.93	1.08	Mg	0.68	0.6			
			Al	6.51	7.74	Si	18.41	22.11	Al	2.44	2.39			
			Si	33.26	41.18	S	0.16	0.23	Si	7.32	7.44			

	K	1.73	2.98	Ca	0.53	0.91	S	2.66	3.08			
	Ca	1.49	2.63	Ti	0.18	0.38	K	0.43	0.6			
	Ti	0.22	0.46	Mn	0.38	0.9	Ca	0.54	0.78			
	Fe	2.32	5.72	Fe	9.70	23.16	Ti	5.77	10.01			
							Mn	0.92	1.83			
							Fe	18.80	38.01			
MS50	melt: 65.6%			quartz: 14.5%			orthopyroxene: 13.9%			amphibole: 2.7%		
	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %
	O	62.48	52.61	O	66.32	52.61	O	60.93	43.28	O	61.97	42.65
	Na	2.16	0.71	Al	0.53	0.71	Na	0.84	0.85	Na	1.48	1.46
	Mg	0.53	45.29	Si	32.52	45.29	Mg	5.85	6.31	Mg	1.08	1.13
	Al	7.00	0.55	K	0.28	0.55	Al	2.80	3.35	Al	4.32	5.02
	Si	22.83	0.26	Ca	0.13	0.26	Si	20.84	25.99	Si	18.00	21.74
	P	0.10	0.58	Fe	0.21	0.58	K	0.66	1.15	P	0.17	0.23
	K	1.46	52.61				Ca	1.25	2.22	S	0.17	0.23
	Ca	1.89	0.71				Ti	0.32	0.69	K	1.31	2.20
	Ti	0.26	45.29				V	0.02	0.05	Ca	1.10	1.89
	Fe	1.21	0.55				Mn	0.14	0.34	Ti	4.58	9.44
	Ba	0.05	0.26				Fe	6.36	15.77	Fe	5.83	14.00
	Os	0.03	0.58									
	pyrite: 0.01%											
	element	atomic %	Wt %									
	O	64.13	39.19									
	Al	0.80	0.82									
	Si	3.56	3.82									
	S	12.15	14.88									
	Fe	19.36	41.29									
MS51	melt: 94.0%			orthopyroxene: 4.1%			amphibole: 1.1%					
	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %			
	O	63.14	47.82	O	59.96	42.50	O	61.19	38.39			
	Na	1.60	1.75	Mg	11.29	12.17	Na	1.02	0.92			
	Mg	0.70	0.80	Al	1.09	1.31	Mg	1.20	1.15			
	Al	5.24	6.70	Si	19.25	23.96	Al	2.73	2.88			
	Si	24.76	32.91	K	0.12	0.22	Si	10.96	12.07			
	K	1.16	2.14	Ca	0.80	1.43	S	2.28	2.87			

	Ca	1.50	2.85	Ti	0.18	0.38	K	0.65	0.99			
	Ti	0.29	0.65	Mn	0.24	0.57	Ca	1.57	2.47			
	Fe	1.57	4.16	Fe	7.06	17.47	Ti	6.32	11.88			
	Ba	0.04	0.23				Mn	1.79	3.85			
							Fe	10.29	22.53			
MS52	melt: 66.8%			orthopyroxene: 12.1%			plagioclase: 10.4%			clinopyroxene: 7.7%		
	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %
	O	62.93	47.66	O	59.76	42.30	O	61.83	46.69	O	61.08	44.69
	Na	1.54	1.68	Mg	12.13	13.04	Na	1.47	1.59	Na	0.73	0.77
	Mg	0.90	1.03	Si	20.40	25.34	Mg	0.31	0.36	Mg	6.15	6.84
	Al	6.03	7.71	K	0.10	0.17	Al	11.82	15.06	Al	3.45	4.25
	Si	23.80	31.64	Ca	0.90	1.59	Si	18.61	24.66	Si	20.79	26.70
	K	0.92	1.71	Ti	0.10	0.22	K	0.26	0.47	K	0.35	0.62
	Ca	2.13	4.03	Mn	0.11	0.27	Ca	5.20	9.83	Ca	3.96	7.27
	Ti	0.27	0.60	Fe	5.57	13.77	Fe	0.51	1.34	Ti	0.18	0.39
	V	0.00	0.01	Br	0.93	3.30				Mn	0.09	0.21
	Fe	1.49	3.93							Fe	3.23	8.25
	pyrite: 0.8%											
	element	atomic %	Wt %									
	O	65.67	40.95									
	Si	1.87	2.04									
	S	14.73	18.41									
	Fe	17.73	38.60									
MS53	melt: 68.0%			clinopyroxene: 25.3%			orthopyroxene: 5.1%			FeTi oxides: 0.4%		
	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %
	O	61.66	46.66	O	60.42	43.55	O	59.83	42.68	O	57.89	31.17
	Na	2.87	3.12	Na	0.89	0.93	Mg	12.08	13.10	Mg	2.50	2.05
	Mg	0.58	0.67	Mg	6.86	7.51	Al	1.41	1.70	Al	1.68	1.53
	Al	9.73	12.41	Al	3.47	4.22	Si	18.80	23.55	Si	2.72	2.57
	Si	20.01	26.58	Si	19.49	24.66	Ca	0.80	1.42	Ca	0.42	0.56
	K	0.61	1.13	K	0.30	0.52	Ti	0.15	0.32	Ti	12.21	19.68
	Ca	3.38	6.40	Ca	4.08	7.36	Mn	0.13	0.33	Fe	22.58	42.44
	Ti	0.18	0.41	Ti	0.21	0.45	Fe	6.79	16.90			
	Fe	1.00	2.63	Mn	0.10	0.25						
				Fe	4.19	10.55						

MS58	melt: 82.8%			orthopyroxene: 8.6%			clinopyroxene: 6.1%					
	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %			
	O	62.47	46.70	O	58.11	42.18	O	59.74	43.48			
	Na	1.43	1.54	Mg	14.14	15.60	Na	0.57	0.60			
	Mg	1.32	1.50	Al	1.23	1.50	Mg	7.68	8.50			
	Al	6.46	8.14	Si	20.43	26.03	Al	3.11	3.82			
	Si	22.84	29.98	K	0.04	0.08	Si	20.98	26.81			
	K	0.77	1.40	Ca	0.94	1.71	K	0.27	0.47			
	Ca	2.62	4.91	Ti	0.07	0.16	Ca	4.25	7.75			
	Ti	0.25	0.56	Cr	0.04	0.10	Ti	0.15	0.32			
Fe	1.77	4.62	Mn	0.11	0.27	Mn	0.09	0.23				
			Fe	4.89	12.38	Fe	3.16	8.03				
MS59	melt: 66.1%			clinopyroxene: 0.5%			orthopyroxene: 0.2%					
	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %			
	O	61.86	46.16	O	59.94	42.75	O	60.07	43.69			
	Na	2.48	2.65	Na	0.44	0.45	Mg	12.52	13.84			
	Mg	1.34	1.52	Mg	7.77	8.42	Al	1.23	1.51			
	Al	6.83	8.59	Al	2.31	2.77	Si	19.53	24.93			
	Si	21.59	28.28	Si	18.57	23.25	Ca	1.14	2.07			
	K	0.96	1.75	Ca	6.89	12.31	Fe	5.50	13.96			
	Ca	2.27	4.25	Ti	0.37	0.79						
	Ti	0.44	0.98	Fe	3.72	9.26						
Fe	2.23	5.81										
MS60	quartz: 45.4%			melt: 27.4%			biotite: 5.2%			pyrite: 0.9%		
	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %	element	atomic %	Wt %
	O	66.31	52.63	O	62.10	47.10	O	61.01	44.06	O	64.07	41.91
	Al	0.73	0.98	Na	1.61	1.76	Na	0.72	0.75	Mg	2.59	2.57
	Si	32.38	45.12	Mg	1.31	1.51	Mg	5.40	5.92	Al	2.20	2.43
	K	0.30	0.58	Al	8.26	10.56	Al	6.63	8.08	Si	7.33	8.42
	Ca	0.07	0.14	Si	22.32	29.71	Si	19.04	24.15	S	9.46	12.41
	Ti	0.03	0.08	Ar	0.22	0.42	S	0.12	0.17	K	0.27	0.43
	Fe	0.17	0.47	K	2.72	5.05	Ar	0.10	0.18	Ti	0.92	1.79
				Ca	0.36	0.67	K	1.06	1.87	Fe	13.16	30.04
				Ti	0.12	0.26	Ca	0.16	0.30			
				V	0.02	0.05	Ti	0.36	0.77			

APPENDIX D: PARTIAL MELT MODELING

Fig. D1 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS1. A shows the results of the batch melt model; B shows the results of the fractional melt model. The melt percentages are approximately $\pm 20\%$ that observed in the experimental melt. The trace element concentrations of the parent material, sample MS12-47 (biotite fels), are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH31, which is included for comparison, are indicated by the yellow squares. For experimental melt MS1, it can be seen that the batch melt model (A) approximates the data. The fit increases as melt percent increases.

Fig. D2 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS3. A shows the results of the batch melt model; B shows the results of the fractional melt model. The melt percentages are approximately $\pm 20\%$ that observed in the experimental melt. The trace element concentrations of the parent material, sample TM13-5 (amphibolite), are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH31, which is included for comparison, are indicated by the yellow squares. Neither model is a satisfactory fit for experimental melt MS3.

Fig. D3 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS4. A shows the results of the batch melt model; B shows the results of the fractional melt model. The melt percentages are approximately $\pm 20\%$ that observed in the experimental melt. The trace element concentrations of the parent material, sample MS12-47 (biotite fels), are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH31, which is included for comparison, are indicated by the yellow squares. For experimental melt MS4, it can be seen that the batch melt model (A) approximates the data. The fit increases as melt percent increases.

Fig. D4 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS5. A shows the results of the batch melt model; B shows the results of the fractional melt model. The melt percentages are approximately $\pm 20\%$ that observed in the experimental melt. The trace element concentrations of the parent material, sample TM13-3 (granodiorite), are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH31, which is included for comparison, are indicated by the yellow squares. For experimental melt MS5, it can be seen that the batch melt model (A) approximates the data. The fit increases as melt percent increases.

Fig. D5 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS6. A shows the results of the batch melt model; B shows the results of the fractional melt model. The melt percentages are approximately $\pm 20\%$ that observed in the experimental melt. The trace element concentrations of the parent material, sample TM13-5 (amphibolite), are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH31, which is included for comparison, are indicated by the yellow squares. For experimental melt MS6, it can be seen that the batch melt model (A) approximates the data, although there are notable exceptions at Sr and Eu. In general, the fit increases as melt percent increases.

Fig. D6 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS8. A shows the results of the batch melt model; B shows the results of the fractional melt model. The melt percentages are approximately $\pm 20\%$ that observed in the experimental melt. The trace element concentrations of the parent material, sample TM13-3 (granodiorite), are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH31, which is included for comparison, are indicated by the yellow squares. For experimental melt MS8, it can be seen that batch melt model (A) approximates the data. The fit increases as melt percent increases.

Fig. D7 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS9. A shows the results of the batch melt model; B shows the results of the fractional melt model. The melt percentages are approximately $\pm 20\%$ that observed in the experimental melt. The trace element concentrations of the parent material, sample TM13-5 (amphibolite), are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH31, which is included for comparison, are indicated by the yellow squares. For experimental melt MS9, it can be seen that batch melt model (A) approximates the data. The fit increases as melt percent increases.

Fig. D8 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS13. A shows the results of the batch melt model; B shows the results of the fractional melt model. The melt percentages are approximately $\pm 20\%$ that observed in the experimental melt. The trace element concentrations of the parent material, sample TM13-3 (granodiorite), are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH31, which is included for comparison, are indicated by the yellow squares. For experimental melt MS13, it can be seen that the batch melt model (A) approximates the data. The fit increases as melt percent increases.

Fig. D9 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS15. A shows the results of the batch melt model; B shows the results of the fractional melt model. The melt percentages are approximately $\pm 20\%$ that observed in the experimental melt. The trace element concentrations of the parent material, sample MS12-47 (biotite fels) are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH31, which is included for comparison, are indicated by the yellow squares. For experimental melt MS15, it can be seen that the batch melt model (A) approximates the data. The fit increases as melt percent increases.

Fig. D10 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS16. A shows the results of the batch melt model; B shows the results of the fractional melt model. The melt percentages are approximately $\pm 20\%$ that observed in the experimental melt. The trace element concentrations of the parent material, sample TM13-3 (granodiorite), are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH31, which is included for comparison, are indicated by the yellow squares. For experimental melt MS16, it can be seen that the batch melt model (A) approximates the data. The fit increases as melt percent increases.

Fig. D11 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS17. A shows the results of the batch melt model; B shows the results of the fractional melt model. The melt percentages are approximately $\pm 20\%$ that observed in the experimental melt. The trace element concentrations of the parent material, sample TM13-5 (amphibolite), are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH31, which is included for comparison, are indicated by the yellow squares. For experimental melt MS17, it can be seen that the batch melt model (A) approximates the data with notable exceptions at Sr and Eu. In general, the fit increases as melt percent increases.

Fig. D12 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS18. A shows the results of the batch melt model; B shows the results of the fractional melt model. The melt percentages are approximately $\pm 20\%$ that observed in the experimental melt. The trace element concentrations of the parent material, sample MS12-47 (biotite fels), are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH31, which is included for comparison, are indicated by the yellow squares. For experimental melt MS18, it can be seen that the batch melt model (A) approximates the data, with a notable exception at Eu. In general, the fit increases as melt percent increases.

Fig. D13 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS19. A shows the results of the batch melt model; B shows the results of the fractional melt model. The melt percentages are approximately $\pm 20\%$ that observed in the experimental melt. The trace element concentrations of the parent material, sample TM13-5 (amphibolite), are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH31, which is included for comparison, are indicated by the yellow squares. For experimental melt MS19, it can be seen that the batch melt model (A) approximates the data, although there are notable exceptions at Sr and Eu. In general, the fit increases as melt percent increases.

Fig. D14 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS22. A shows the results of the batch melt model; B shows the results of the fractional melt model. The melt percentages are approximately $\pm 20\%$ that observed in the experimental melt. The trace element concentrations of the parent material, sample TM13-5 (amphibolite), are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH31, which is included for comparison, are indicated by the yellow squares. For experimental melt MS22, it can be seen that the batch melt model (A) approximates the data. The fit increases as melt percent increases, particularly for LREE.

Fig. D15 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS23. A shows the results of the batch melt model; B shows the results of the fractional melt model. The melt percentages are approximately $\pm 20\%$ that observed in the experimental melt. The trace element concentrations of the parent material, sample TM13-1 (biotite schist), are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH31, which is included for comparison, are indicated by the yellow squares. For experimental melt MS23, it can be seen that the batch melt model (A) approximates the data, although there are notable exceptions at Ba, Sr, Zr, and Eu. In general, the fit increases as melt percent increases.

Fig. D16 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS26. A shows the results of the batch melt model; B shows the results of the fractional melt model. The melt percentages are approximately $\pm 20\%$ that observed in the experimental melt. The trace element concentrations of the parent material, sample 50M2C (50/50 mixture of mafic glass and diorite), are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH31, which is included for comparison, are indicated by the yellow squares. For experimental melt MS26, it can be seen that the batch melt model (A) approximates the data. The fit increases as melt percent increases, particularly for LREE.

Fig. D17 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS27. A shows the results of the batch melt model; B shows the results of the fractional melt model. The melt percentages are approximately $\pm 20\%$ that observed in the experimental melt. The trace element concentrations of the parent material, sample 50M3A (50/50 mixture of mafic glass and biotite fels), are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH31, which is included for comparison, are indicated by the yellow squares. For experimental melt MS27, it can be seen that the batch melt model (A) approximates the data. The fit increases as melt percent increases.

Fig. D18 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS28. A shows the results of the batch melt model; B shows the results of the fractional melt model. The melt percentages are approximately $\pm 20\%$ that observed in the experimental melt. The trace element concentrations of the parent material, sample 50M3B (50/50 mixture of mafic glass and biotite schist), are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH31, which is included for comparison, are indicated by the yellow squares. For experimental melt MS28, it can be seen that the batch melt model (A) approximates the data. The fit increases as melt percent increases.

Fig. D19 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS29. A shows the results of the batch melt model; B shows the results of the fractional melt model. The melt percentages are approximately $\pm 20\%$ that observed in the experimental melt. The trace element concentrations of the parent material, sample 50M3C (50/50 mixture of mafic glass and diorite), are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH31, which is included for comparison, are indicated by the yellow squares. For experimental melt MS29, it can be seen that the batch melt model (A) approximates the data. The fit increases as melt percent increases.

Fig. D20 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS30. A shows the results of the batch melt model; B shows the results of the fractional melt model. The melt percentages are approximately $\pm 20\%$ that observed in the experimental melt. The trace element concentrations of the parent material, sample 50M1A (50/50 mixture of mafic glass and biotite fels), are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH31, which is included for comparison, are indicated by the yellow squares. For experimental melt MS30, it can be seen that the batch melt model (A) approximates the data. The fit increases as melt percent increases.

Fig. D21 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS33. A shows the results of the batch melt model; B shows the results of the fractional melt model. The melt percentages are approximately $\pm 20\%$ that observed in the experimental melt. The trace element concentrations of the parent material, sample 50M1D (50/50 mixture of mafic glass and amphibolite), are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH31, which is included for comparison, are indicated by the yellow squares. For experimental melt MS33, it can be seen that the batch melt model (A) approximates the data. The fit increases as melt percent increases, particularly for LREE.

Fig. D22 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS34. A shows the results of the batch melt model; B shows the results of the fractional melt model. The melt percentages are approximately $\pm 20\%$ that observed in the experimental melt. The trace element concentrations of the parent material, sample 50M2D (50/50 mixture of mafic glass and amphibolite), are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH31, which is included for comparison, are indicated by the yellow squares. For experimental melt MS34, it can be seen that the batch melt model (A) approximates the data. The fit increases as melt percent increases, particularly for LREE.

Fig. D23 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS35. A shows the results of the batch melt model; B shows the results of the fractional melt model. The melt percentages are approximately $\pm 20\%$ that observed in the experimental melt. The trace element concentrations of the parent material, sample 50M3D (50/50 mixture of mafic glass and amphibolite), are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH31, which is included for comparison, are indicated by the yellow squares. For experimental melt MS35, it can be seen that the batch melt model (A) approximates the data. The fit increases as melt percent increases, particularly for LREE.

Fig. D24 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS37. A shows the results of the batch melt model; B shows the results of the fractional melt model. The melt percentages are approximately $\pm 20\%$ that observed in the experimental melt. The trace element concentrations of the parent material, sample TM13-1 (biotite schist) are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH31, which is included for comparison, are indicated by the yellow squares. For experimental melt MS37, it can be seen that the batch melt model (A) approximates the data with a notable exception at Ba. The fit increases as melt percent increases, particularly for LREE.

Fig. D25 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS38. A shows the results of the batch melt model; B shows the results of the fractional melt model. The melt percentages are approximately $\pm 20\%$ that observed in the experimental melt. The trace element concentrations of the parent material, sample TM13-3 (granodiorite), are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH38, which is included for comparison, are indicated by the yellow squares. For experimental melt MS38, it can be seen that the batch melt model (A) approximates the data with notable exceptions at Sr and Eu. The fit increases as melt percent increases.

Fig. D26 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS39. A shows the results of the batch melt model; B shows the results of the fractional melt model. The melt percentages are approximately $\pm 20\%$ that observed in the experimental melt. The trace element concentrations of the parent material, sample TM13-3 (granodiorite), are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH31, which is included for comparison, are indicated by the yellow squares. For experimental melt MS39, it can be seen that the batch melt model (A) approximates the data. The fit increases as melt percent increases.

Fig. D27 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS40. A shows the results of the batch melt model; B shows the results of the fractional melt model. The melt percentages are approximately $\pm 20\%$ that observed in the experimental melt. The trace element concentrations of the parent material, sample TM13-5 (amphibolite), are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH31, which is included for comparison, are indicated by the yellow squares. For experimental melt MS40, it can be seen that the batch melt model (A) approximates the data with notable exceptions at Pb and HREE. In general, the fit increases as melt percent increases.

Fig. D28 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS41. A shows the results of the batch melt model; B shows the results of the fractional melt model. The melt percentages are approximately $\pm 20\%$ that observed in the experimental melt. The trace element concentrations of the parent material, sample TM13-5 (amphibolite), are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH31, which is included for comparison, are indicated by the yellow squares. For experimental melt MS41, it can be seen that the batch melt model (A) approximates the data with notable exceptions at Pb, Zr, Hf, and HREE. In general, the fit increases as melt percent increases.

Fig. D29 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS43. A shows the results of the batch melt model; B shows the results of the fractional melt model. The melt percentages are approximately $\pm 20\%$ that observed in the experimental melt. The trace element concentrations of the parent material, sample 50M2B (50/50 mixture of mafic glass and biotite schist), are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH31, which is included for comparison, are indicated by the yellow squares. For experimental melt MS43, it can be seen that the batch melt model (A) approximates the data. Fit increases as melt percent increases.

Fig. D30 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS44. A shows the results of the batch melt model; B shows the results of the fractional melt model. The melt percentages are approximately $\pm 20\%$ that observed in the experimental melt. The trace element concentrations of the parent material, sample 50M2C (50/50 mixture of mafic glass and diorite), are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH31, which is included for comparison, are indicated by the yellow squares. For experimental melt MS44, it can be seen that the batch melt model (A) approximates the data with a notable exception at Th. In general, the fit increases as melt percent increases.

Fig. D31 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS45. A shows the results of the batch melt model; B shows the results of the fractional melt model. The melt percentages are approximately $\pm 20\%$ that observed in the experimental melt. The trace element concentrations of the parent material, sample 50M3A (50/50 mixture of mafic glass and biotite fels), are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH31, which is included for comparison, are indicated by the yellow squares. For experimental melt MS45, it can be seen that the batch melt model (A) approximates the data. The fit increases as melt percent increases.

Fig. D32 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS46. A shows the results of the batch melt model; B shows the results of the fractional melt model. The melt percentages are approximately $\pm 20\%$ that observed in the experimental melt. The trace element concentrations of the parent material, sample 50M3B (50/50 mixture of mafic glass and biotite schist), are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH31, which is included for comparison, are indicated by the yellow squares. For experimental melt MS46, it can be seen that the batch melt model (A) approximates the data with a notable exception at Ba. The fit increases as melt percent increases.

Fig. D33 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS47. A shows the results of the batch melt model; B shows the results of the fractional melt model. The melt percentages are approximately $\pm 20\%$ that observed in the experimental melt. The trace element concentrations of the parent material, sample 50M3C (50/50 mixture of mafic glass and diorite), are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH31, which is included for comparison, are indicated by the yellow squares. For experimental melt MS47, it can be seen that the batch melt model (A) approximates the data, with a notable exception at Nd. In general, the fit increases as melt percent increases, particularly for LREE.

Fig. D34 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS48. A shows the results of the batch melt model; B shows the results of the fractional melt model. The melt percentages are approximately $\pm 20\%$ that observed in the experimental melt. The trace element concentrations of the parent material, sample 50M3A (50/50 mixture of mafic glass and biotite fels), are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH31, which is included for comparison, are indicated by the yellow squares. For experimental melt MS48, it can be seen that the batch melt model (A) approximates the data. The fit increases as melt percent increases.

Fig. D35 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS49. A shows the results of the batch melt model; B shows the results of the fractional melt model. The melt percentages are approximately - 20% that observed in the experimental melt. The trace element concentrations of the parent material, sample 50M3A (50/50 mixture of mafic glass and biotite fels), are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH31, which is included for comparison, are indicated by the yellow squares. For experimental melt MS49, it can be seen that the batch model (A) approximates the data.

Fig. D36 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS50. A shows the results of the batch melt model; B shows the results of the fractional melt model. The melt percentages are approximately $\pm 20\%$ that observed in the experimental melt. The trace element concentrations of the parent material, sample 50M2A (50/50 mixture of mafic glass and biotite fels), are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH31, which is included for comparison, are indicated by the yellow squares. For experimental melt MS50, it can be seen that the batch melt model (A) approximates the data. The fit increases as melt percent increases.

Fig. D37 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS51. A shows the results of the batch melt model; B shows the results of the fractional melt model. The melt percentages are approximately $\pm 20\%$ that observed in the experimental melt. The trace element concentrations of the parent material, sample 50M2A (50/50 mixture of mafic glass and biotite fels), are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH31, which is included for comparison, are indicated by the yellow squares. For experimental melt MS51, it can be seen that the batch melt model (A) approximates the data. The fit increases as melt percent increases.

Fig. D38 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS52. A shows the results of the batch melt model; B shows the results of the fractional melt model. The melt percentages are approximately $\pm 20\%$ that observed in the experimental melt. The trace element concentrations of the parent material, sample 50M1A (50/50 mixture of mafic glass and biotite fels), are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH31, which is included for comparison, are indicated by the yellow squares. For experimental melt MS52, it can be seen that the batch melt model (A) approximates the data. The fit increases as melt percent increases.

Fig. D39 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS53. A shows the results of the batch melt model; B shows the results of the fractional melt model. The melt percentages are approximately $\pm 20\%$ that observed in the experimental melt. The trace element concentrations of the parent material, sample 50M1A (50/50 mixture of mafic glass and biotite fels), are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH31, which is included for comparison, are indicated by the yellow squares. For experimental melt MS53, it can be seen that the batch melt model (A) approximates the data. The fit increases as melt percent increases.

Fig. D40 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS55. A shows the results of the batch melt model; B shows the results of the fractional melt model. The melt percentages are approximately $\pm 20\%$ that observed in the experimental melt. The trace element concentrations of the parent material, sample 50M1B (50/50 mixture of mafic glass and biotite schist), are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH31, which is included for comparison, are indicated by the yellow squares. For experimental melt MS55, it can be seen that the batch melt model (A) approximates the data. The fit increases as melt percent increases.

Fig. D41 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS57. A shows the results of the batch melt model; B shows the results of the fractional melt model. The melt percentages are approximately $\pm 20\%$ that observed in the experimental melt. The trace element concentrations of the parent material, sample 50M1D (50/50 mixture of mafic glass and biotite fels), are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH31, which is included for comparison, are indicated by the yellow squares. For experimental melt MS57, it can be seen that the batch melt model (A) approximates the data. The fit increases as melt percent increases.

Fig. D42 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS58. A shows the results of the batch melt model; B shows the results of the fractional melt model. The melt percentages are approximately $\pm 20\%$ that observed in the experimental melt. The trace element concentrations of the parent material, sample 50M1A (50/50 mixture of mafic glass and biotite fels), are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH31, which is included for comparison, are indicated by the yellow squares. For experimental melt MS58, it can be seen that the batch melt model (A) approximates the data. The fit increases as melt percent increases.

Fig. D43 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS59. A shows the results of the batch melt model; B shows the results of the fractional melt model. The melt percentages are approximately $\pm 20\%$ that observed in the experimental melt. The trace element concentrations of the parent material, sample 50M2C (50/50 mixture of mafic glass and diorite), are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH31, which is included for comparison, are indicated by the yellow squares. For experimental melt MS59, it can be seen that the batch melt model (A) approximates the data with a notable exception at Th. In general, the fit increases as melt percent increases, particularly for LREE.

Fig. D44 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS60. A shows the results of the batch melt model; B shows the results of the fractional melt model. The melt percentages are approximately $\pm 20\%$ that observed in the experimental melt. The trace element concentrations of the parent material, sample MS12-47 (biotite fels), are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH31, which is included for comparison, are indicated by the yellow squares. For experimental melt MS60, it can be seen that the batch melt model (A) approximates the data. The fit increases as melt percent increases.

Fig. D45 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS62. A shows the results of the batch melt model; B shows the results of the fractional melt model. The melt percentages are approximately $\pm 20\%$ that observed in the experimental melt. The trace element concentrations of the parent material, sample 50M2A (50/50 mixture of mafic glass and biotite fels), are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH31, which is included for comparison, are indicated by the yellow squares. For experimental melt MS62, it can be seen that the batch melt model (A) approximates the data with a notable exception at Ba. The fit increases as melt percent increases.

Fig. D46 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS63. A shows the results of the batch melt model; B shows the results of the fractional melt model. The melt percentages are approximately $\pm 20\%$ that observed in the experimental melt. The trace element concentrations of the parent material, sample 50M2A (50/50 mixture of mafic glass and biotite fels), are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH31, which is included for comparison, are indicated by the yellow squares. For experimental melt MS63, it can be seen that the batch melt model (A) approximates the data. The fit increases as melt percent increases.

Fig. D47 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram for the partial melting of experimental melt MS65. A shows the results of the batch melt model; B shows the results of the fractional melt model. The melt percentages are approximately $\pm 20\%$ that observed in the experimental melt. The trace element concentrations of the parent material, sample 50MAB (50/50 mixture of biotite fels and biotite schist), are indicated by the black diamonds. The trace element concentrations of the Dale Tuff, sample CH31, which is included for comparison, are indicated by the yellow squares. For experimental melt MS65, it can be seen that the batch melt model (A) approximates the data. The fit increases as melt percent increases.

Table D1: Results of batch partial melting calculations

MS1	Element	Melt Fraction								
		0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95
	Rb	119.042	109.204	100.868	93.715	87.509	82.074	77.274	73.005	69.183
	Ba	4496.786	4125.166	3810.280	3540.057	3305.624	3100.312	2919.012	2757.746	2613.365
	Th	12.788	11.731	10.836	10.067	9.400	8.817	8.301	7.842	7.432
	U	4.148	3.805	3.514	3.265	3.049	2.860	2.692	2.544	2.410
	Nb	13.098	12.015	11.098	10.311	9.628	9.030	8.502	8.032	7.612
	Ta	1.141	1.047	0.967	0.898	0.839	0.787	0.741	0.700	0.663
	La	35.950	32.984	30.471	28.313	26.441	24.801	23.352	22.063	20.910
	Ce	72.835	66.827	61.734	57.362	53.569	50.246	47.311	44.701	42.363
	Pb	9.877	9.062	8.371	7.778	7.264	6.813	6.415	6.061	5.744
	Pr	8.464	7.767	7.176	6.669	6.228	5.842	5.502	5.198	4.927
	Sr	131.268	120.431	111.247	103.365	96.525	90.535	85.245	80.538	76.325
	Nd	31.118	28.559	26.390	24.527	22.909	21.492	20.240	19.126	18.128
	Zr	160.053	146.941	135.814	126.254	117.952	110.674	104.242	98.516	93.387
	Hf	4.307	3.954	3.654	3.397	3.174	2.978	2.805	2.651	2.513
	Sm	6.005	5.514	5.098	4.740	4.430	4.157	3.916	3.701	3.509
	Eu	1.081	0.993	0.919	0.855	0.799	0.750	0.707	0.668	0.634
	Tb	0.847	0.779	0.721	0.671	0.628	0.590	0.556	0.526	0.499
	Dy	5.213	4.808	4.461	4.161	3.899	3.668	3.463	3.279	3.114
	Y	26.249	24.363	22.730	21.302	20.043	18.924	17.924	17.024	16.211
	Yb	2.738	2.562	2.407	2.270	2.147	2.037	1.938	1.848	1.766
	Lu	0.451	0.422	0.396	0.373	0.352	0.334	0.318	0.303	0.289
MS3	Element	Melt Fraction								
		0.01	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40
	Rb	60.956	21.461	11.857	8.192	6.257	5.062	4.250	3.663	3.218
	Ba	404.318	294.225	219.511	175.057	145.576	124.594	108.898	96.714	86.983
	Th	6.375	2.132	1.164	0.800	0.610	0.493	0.413	0.356	0.312
	U	3.489	1.167	0.637	0.438	0.334	0.270	0.226	0.195	0.171
	Nb	69.870	22.696	12.308	8.444	6.426	5.187	4.348	3.743	3.286
	Ta	4.441	1.443	0.782	0.537	0.408	0.330	0.276	0.238	0.209
	La	20.868	18.303	15.866	14.002	12.529	11.337	10.352	9.525	8.820
	Ce	27.920	26.644	25.204	23.911	22.745	21.687	20.723	19.841	19.031
	Pb	4.588	3.347	2.501	1.997	1.662	1.423	1.244	1.105	0.994
	Pr	2.283	2.269	2.252	2.236	2.219	2.203	2.187	2.172	2.156
	Sr	277.433	279.052	281.101	283.182	285.293	287.436	289.611	291.819	294.062
	Nd	5.882	5.981	6.110	6.244	6.385	6.532	6.686	6.848	7.017
	Zr	214.710	180.933	151.201	129.862	113.801	101.275	91.233	83.003	76.135
	Hf	6.407	5.399	4.512	3.875	3.396	3.022	2.722	2.477	2.272

	Sm	0.894	0.920	0.955	0.993	1.033	1.078	1.126	1.178	1.236
	Eu	0.262	0.271	0.282	0.294	0.308	0.323	0.339	0.357	0.377
	Tb	0.120	0.124	0.129	0.135	0.141	0.148	0.156	0.164	0.173
	Dy	0.782	0.807	0.841	0.877	0.916	0.959	1.007	1.059	1.117
	Y	4.136	4.265	4.439	4.627	4.832	5.056	5.302	5.573	5.873
	Yb	0.491	0.505	0.523	0.543	0.565	0.588	0.614	0.642	0.672
	Lu	0.080	0.082	0.085	0.088	0.092	0.096	0.100	0.104	0.109
MS4	Element	Melt Fraction								
		0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60
	Rb	318.804	256.978	215.237	185.161	162.460	144.718	130.469	118.774	109.004
	Ba	9578.089	8126.958	7057.682	6237.063	5587.398	5060.306	4624.089	4257.111	3944.098
	Th	34.431	27.717	23.195	19.941	17.488	15.572	14.035	12.773	11.720
	U	11.168	8.990	7.523	6.468	5.672	5.051	4.552	4.143	3.801
	Nb	35.265	28.389	23.757	20.424	17.911	15.949	14.374	13.083	12.004
	Ta	3.073	2.474	2.070	1.780	1.561	1.390	1.253	1.140	1.046
	La	83.489	69.568	59.626	52.171	46.372	41.734	37.939	34.777	32.101
	Ce	177.388	146.252	124.414	108.250	95.804	85.924	77.891	71.232	65.622
	Pb	21.931	18.451	15.924	14.006	12.500	11.287	10.288	9.452	8.741
	Pr	20.757	17.090	14.524	12.628	11.170	10.014	9.074	8.296	7.641
	Sr	83.580	82.792	82.018	81.259	80.513	79.782	79.063	78.357	77.664
	Nd	77.227	63.423	53.805	46.720	41.284	36.981	33.491	30.602	28.172
	Zr	424.137	343.115	288.083	248.264	218.116	194.497	175.494	159.873	146.806
	Hf	11.413	9.233	7.752	6.680	5.869	5.234	4.722	4.302	3.950
	Sm	15.100	12.373	10.480	9.090	8.025	7.183	6.502	5.938	5.464
	Eu	1.231	1.155	1.089	1.029	0.976	0.928	0.885	0.845	0.809
	Tb	2.089	1.723	1.466	1.275	1.129	1.012	0.918	0.839	0.773
	Dy	12.302	10.279	8.827	7.735	6.883	6.200	5.640	5.174	4.778
	Y	55.697	47.911	42.035	37.443	33.755	30.729	28.200	26.056	24.216
	Yb	5.157	4.572	4.106	3.726	3.410	3.144	2.916	2.719	2.547
	Lu	0.866	0.764	0.684	0.619	0.565	0.520	0.481	0.448	0.419
MS5	Element	Melt Fraction								
		0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90
	Rb	86.841	79.038	72.522	66.999	62.257	58.142	54.537	51.353	48.521
	Ba	1422.565	1300.559	1197.828	1110.139	1034.412	968.357	910.232	858.690	812.672
	Th	7.486	6.818	6.259	5.785	5.377	5.023	4.713	4.439	4.195
	U	2.911	2.651	2.434	2.250	2.091	1.954	1.833	1.726	1.632
	Nb	11.046	10.093	9.291	8.607	8.017	7.502	7.050	6.649	6.291
	Ta	0.910	0.832	0.766	0.710	0.662	0.620	0.583	0.550	0.520
	La	28.371	26.545	24.940	23.518	22.250	21.111	20.084	19.151	18.302
	Ce	52.842	49.829	47.141	44.728	42.550	40.575	38.774	37.127	35.614
	Pb	12.880	11.771	10.837	10.041	9.353	8.754	8.227	7.760	7.343

	Pr	6.551	6.189	5.864	5.571	5.307	5.066	4.847	4.645	4.460	
	Sr	860.398	819.509	782.329	748.377	717.249	688.607	662.165	637.679	614.939	
	Nd	24.275	23.204	22.224	21.323	20.492	19.724	19.011	18.348	17.730	
	Zr	192.395	175.809	161.856	149.955	139.684	130.730	122.855	115.875	109.645	
	Hf	5.231	4.779	4.400	4.076	3.796	3.553	3.339	3.149	2.979	
	Sm	4.822	4.653	4.496	4.349	4.212	4.083	3.961	3.847	3.739	
	Eu	1.267	1.244	1.222	1.201	1.180	1.160	1.141	1.122	1.104	
	Tb	0.680	0.653	0.628	0.605	0.583	0.563	0.544	0.527	0.510	
	Dy	4.341	4.127	3.933	3.757	3.596	3.448	3.312	3.186	3.069	
	Y	17.947	17.600	17.266	16.944	16.634	16.336	16.048	15.769	15.501	
	Yb	2.107	2.006	1.914	1.830	1.753	1.682	1.617	1.557	1.501	
	Lu	0.369	0.348	0.329	0.312	0.297	0.283	0.271	0.259	0.249	
MS6	Element	Melt Fraction									
		0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	
	Rb	2.824	2.552	2.328	2.140	1.980	1.842	1.722	1.617	1.524	
	Ba	55.419	53.376	51.479	49.711	48.061	46.517	45.069	43.709	42.428	
	Th	0.284	0.256	0.234	0.215	0.198	0.185	0.172	0.162	0.153	
	U	0.153	0.138	0.126	0.116	0.107	0.099	0.093	0.087	0.082	
	Nb	2.921	2.635	2.399	2.203	2.036	1.892	1.768	1.659	1.562	
	Ta	0.176	0.158	0.144	0.132	0.122	0.114	0.106	0.100	0.094	
	La	6.370	6.166	5.975	5.795	5.626	5.466	5.315	5.172	5.037	
	Ce	17.310	16.768	16.259	15.780	15.328	14.902	14.498	14.116	13.754	
	Pb	0.689	0.657	0.628	0.602	0.577	0.555	0.534	0.515	0.497	
	Pr	2.689	2.606	2.528	2.454	2.385	2.319	2.257	2.198	2.142	
	Sr	92.798	99.236	106.633	115.222	125.316	137.348	151.936	169.991	192.916	
	Nd	12.256	12.007	11.768	11.538	11.318	11.105	10.900	10.703	10.512	
	Zr	82.970	74.911	68.279	62.725	58.007	53.950	50.422	47.328	44.591	
	Hf	2.488	2.246	2.048	1.881	1.740	1.618	1.512	1.420	1.338	
	Sm	3.446	3.400	3.355	3.312	3.269	3.228	3.188	3.148	3.110	
	Eu	0.533	0.561	0.591	0.625	0.662	0.705	0.754	0.810	0.874	
	Tb	0.683	0.668	0.654	0.640	0.628	0.615	0.603	0.592	0.581	
	Dy	4.614	4.448	4.293	4.149	4.014	3.888	3.769	3.657	3.552	
	Y	17.275	17.212	17.149	17.086	17.024	16.962	16.900	16.839	16.779	
	Yb	2.486	2.358	2.244	2.139	2.044	1.958	1.878	1.804	1.736	
	Lu	0.422	0.395	0.371	0.350	0.331	0.314	0.298	0.285	0.272	
MS8	Element	Melt Fraction									
		0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70
	Rb	167.695	141.014	121.657	106.973	95.452	86.171	78.535	72.142	66.712	62.042
	Ba	2828.221	2375.935	2048.363	1800.172	1605.625	1449.027	1320.261	1212.512	1121.024	1042.373
	Th	3.275	3.304	3.334	3.365	3.396	3.427	3.459	3.492	3.526	3.560
	U	0.341	0.359	0.380	0.403	0.429	0.458	0.492	0.532	0.578	0.633

		0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90
Rb		86.211	78.568	72.170	66.735	62.062	58.000	54.437	51.287	48.481
Ba		1133.557	1075.036	1022.262	974.426	930.868	891.036	854.474	820.794	789.669
Th		7.501	6.828	6.267	5.791	5.382	5.027	4.716	4.441	4.196
U		2.917	2.655	2.437	2.252	2.093	1.955	1.834	1.727	1.632
Nb		11.271	10.261	9.417	8.701	8.087	7.553	7.086	6.673	6.306
Ta		0.933	0.849	0.779	0.720	0.669	0.625	0.586	0.552	0.522
La		28.493	26.642	25.016	23.577	22.295	21.145	20.108	19.168	18.312
Ce		58.734	54.466	50.776	47.555	44.718	42.200	39.951	37.929	36.102
Pb		10.710	10.089	9.536	9.041	8.594	8.190	7.822	7.485	7.177
Pr		7.430	6.880	6.406	5.993	5.631	5.309	5.022	4.765	4.533
Sr		254.042	269.039	285.917	305.055	326.939	352.205	381.703	416.594	458.505
Nd		30.305	27.997	26.015	24.296	22.789	21.459	20.275	19.215	18.260
Zr		194.445	177.347	163.013	150.823	140.329	131.200	123.187	116.096	109.777
Hf		5.283	4.819	4.429	4.098	3.813	3.565	3.347	3.155	2.983
Sm		6.585	6.064	5.618	5.234	4.899	4.605	4.343	4.110	3.901
Eu		0.860	0.877	0.895	0.913	0.933	0.953	0.975	0.997	1.020
Tb		0.885	0.817	0.758	0.706	0.662	0.623	0.588	0.556	0.528
Dy		5.128	4.751	4.426	4.142	3.893	3.672	3.475	3.297	3.137
Y		24.846	23.313	21.958	20.752	19.672	18.699	17.817	17.015	16.282
Yb		2.104	2.003	1.912	1.828	1.752	1.681	1.616	1.556	1.500
Lu		0.351	0.303	0.318	0.303	0.290	0.278	0.267	0.257	0.247
MS15	Element	Melt Fraction								
		0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60
Rb		321.454	258.549	216.235	185.823	162.911	145.029	130.684	118.921	109.101
Ba		11594.376	9431.352	7948.497	6868.577	6047.002	5400.973	4879.657	4450.120	4090.085
Th		34.586	27.810	23.253	19.980	17.514	15.591	14.048	12.782	11.726
U		11.219	9.020	7.543	6.481	5.681	5.057	4.556	4.146	3.804
Nb		31.492	26.032	22.186	19.330	17.125	15.372	13.944	12.759	11.760
Ta		2.744	2.268	1.933	1.684	1.492	1.339	1.215	1.112	1.025
La		91.495	74.672	63.074	54.595	48.126	43.027	38.905	35.504	32.649
Ce		177.000	146.007	124.250	108.136	95.722	85.865	77.848	71.201	65.599
Pb		26.469	21.337	17.873	15.376	13.491	12.018	10.835	9.864	9.053
Pr		19.233	16.103	13.850	12.149	10.821	9.754	8.879	8.148	7.528
Sr		285.642	241.648	209.397	184.742	165.280	149.529	136.518	125.590	116.282
Nd		67.139	56.847	49.292	43.509	38.940	35.240	32.182	29.612	27.423
Zr		399.450	327.952	278.164	241.500	213.376	191.119	173.066	158.130	145.567
Hf		10.739	8.815	7.475	6.489	5.733	5.134	4.649	4.248	3.910
Sm		10.780	9.462	8.432	7.604	6.924	6.356	5.874	5.459	5.100
Eu		1.806	1.605	1.443	1.312	1.202	1.109	1.030	0.961	0.901
Tb		1.382	1.233	1.112	1.013	0.931	0.860	0.800	0.748	0.701

	Dy	8.633	7.710	6.965	6.351	5.837	5.399	5.023	4.696	4.409
	Y	45.255	40.394	36.477	33.251	30.550	28.255	26.281	24.564	23.058
	Yb	4.822	4.321	3.915	3.578	3.295	3.053	2.845	2.663	2.503
	Lu	0.860	0.762	0.683	0.620	0.567	0.522	0.484	0.451	0.422
MS16	Element	Melt Fraction								
		0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80
	Rb	108.334	96.447	86.910	79.090	72.561	67.027	62.278	58.157	54.548
	Ba	1821.450	1621.284	1460.756	1329.152	1219.302	1126.223	1046.348	977.052	916.364
	Th	9.365	8.338	7.514	6.839	6.275	5.796	5.386	5.030	4.718
	U	3.642	3.243	2.922	2.659	2.440	2.254	2.095	1.956	1.835
	Nb	13.729	12.279	11.106	10.137	9.324	8.632	8.035	7.516	7.060
	Ta	1.131	1.012	0.916	0.837	0.770	0.713	0.664	0.621	0.584
	La	41.491	36.968	33.334	30.351	27.857	25.743	23.926	22.349	20.968
	Ce	81.315	72.444	65.319	59.470	54.582	50.437	46.876	43.786	41.077
	Pb	16.410	14.614	13.172	11.989	11.001	10.163	9.444	8.820	8.274
	Pr	10.199	9.086	8.193	7.459	6.846	6.326	5.879	5.492	5.152
	Sr	1423.738	1267.387	1141.978	1039.153	953.315	880.577	818.151	763.990	716.555
	Nd	41.013	36.539	32.946	29.996	27.530	25.440	23.644	22.085	20.719
	Zr	240.685	215.039	194.332	177.262	162.950	150.775	140.294	131.175	123.169
	Hf	6.547	5.848	5.284	4.819	4.430	4.098	3.813	3.565	3.347
	Sm	8.728	7.778	7.015	6.388	5.864	5.419	5.037	4.705	4.415
	Eu	2.631	2.346	2.116	1.928	1.770	1.636	1.521	1.421	1.334
	Tb	1.177	1.050	0.948	0.864	0.793	0.733	0.682	0.637	0.598
	Dy	6.940	6.203	5.607	5.116	4.703	4.353	4.051	3.788	3.557
	Y	35.469	31.844	28.891	26.439	24.371	22.603	21.074	19.739	18.563
	Yb	3.204	2.893	2.638	2.423	2.241	2.085	1.949	1.829	1.723
	Lu	0.529	0.477	0.435	0.399	0.369	0.343	0.321	0.301	0.283
MS17	Element	Melt Fraction								
		0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75
	Rb	3.579	3.154	2.819	2.548	2.325	2.138	1.978	1.841	1.722
	Ba	61.631	58.998	56.580	54.353	52.294	50.386	48.612	46.958	45.414
	Th	0.362	0.318	0.284	0.256	0.234	0.215	0.198	0.185	0.172
	U	0.195	0.171	0.153	0.138	0.126	0.116	0.107	0.099	0.093
	Nb	3.657	3.223	2.881	2.605	2.377	2.186	2.023	1.883	1.761
	Ta	0.219	0.193	0.173	0.156	0.143	0.131	0.122	0.113	0.106
	La	7.032	6.769	6.525	6.297	6.085	5.887	5.701	5.527	5.363
	Ce	19.119	18.415	17.760	17.151	16.582	16.050	15.551	15.081	14.640
	Pb	0.779	0.738	0.701	0.667	0.636	0.608	0.583	0.559	0.537
	Pr	2.969	2.861	2.760	2.667	2.579	2.497	2.420	2.347	2.279
	Sr	86.678	91.853	97.686	104.309	111.897	120.674	130.946	143.129	157.812
	Nd	13.289	12.959	12.644	12.345	12.059	11.786	11.525	11.276	11.037

	Zr	104.244	91.918	82.199	74.338	67.85	62.403	57.766	53.771	50.292
	Hf	3.127	2.757	2.466	2.23	2.035	1.872	1.733	1.613	1.509
	Sm	3.693	3.629	3.566	3.506	3.448	3.392	3.337	3.285	3.233
	Eu	0.513	0.535	0.56	0.588	0.618	0.651	0.689	0.731	0.778
	Tb	0.74	0.721	0.703	0.686	0.669	0.653	0.638	0.624	0.61
	Dy	5.112	4.9	4.704	4.524	4.357	4.202	4.057	3.922	3.796
	Y	18.001	17.885	17.77	17.657	17.545	17.435	17.326	17.218	17.112
	Yb	2.747	2.595	2.459	2.336	2.226	2.125	2.033	1.949	1.871
	Lu	0.478	0.444	0.415	0.389	0.366	0.346	0.328	0.312	0.297
MS18	Element	Melt Fraction								
		0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45
	Rb	955.471	557.846	393.916	304.449	248.100	209.353	181.073	159.524	142.559
	Ba	5694.414	5331.491	5012.056	4728.736	4475.733	4248.427	4043.094	3856.694	3686.724
	Th	109.069	61.955	43.265	33.239	26.985	22.712	19.607	17.249	15.397
	U	35.378	20.096	14.034	10.781	8.753	7.367	6.360	5.595	4.994
	Nb	89.225	55.874	40.672	31.973	26.339	22.393	19.476	17.231	15.450
	Ta	7.775	4.869	3.544	2.786	2.295	1.951	1.697	1.501	1.346
	La	34.773	33.453	32.229	31.091	30.031	29.041	28.114	27.245	26.427
	Ce	64.434	62.460	60.604	58.854	57.203	55.642	54.164	52.762	51.431
	Pb	15.402	14.055	12.924	11.962	11.134	10.412	9.779	9.218	8.718
	Pr	7.204	7.005	6.817	6.639	6.470	6.309	6.156	6.010	5.871
	Sr	15.832	16.513	17.254	18.066	18.958	19.942	21.034	22.252	23.621
	Nd	20.708	20.491	20.278	20.069	19.864	19.664	19.467	19.275	19.086
	Zr	1133.555	700.714	507.086	397.300	326.592	277.250	240.860	212.914	190.779
	Hf	30.286	18.761	13.590	10.653	8.760	7.438	6.463	5.714	5.121
	Sm	3.292	3.294	3.297	3.299	3.302	3.304	3.307	3.309	3.312
	Eu	0.201	0.208	0.216	0.224	0.233	0.243	0.254	0.266	0.279
	Tb	0.520	0.517	0.515	0.512	0.509	0.506	0.503	0.501	0.498
	Dy	4.274	4.176	4.083	3.994	3.909	3.827	3.748	3.673	3.601
	Y	12.626	12.749	12.875	13.003	13.134	13.268	13.404	13.543	13.685
	Yb	3.447	3.268	3.107	2.961	2.828	2.706	2.595	2.492	2.397
	Lu	0.811	0.738	0.676	0.624	0.580	0.541	0.507	0.477	0.451
MS19	Element	Melt Fraction								
		0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50
	Rb	365.583	259.425	201.045	164.113	138.645	120.019	105.805	94.601	85.543
	Ba	1339.001	1280.371	1226.659	1177.273	1131.709	1089.541	1050.402	1013.978	979.995
	Th	33.455	23.295	17.869	14.493	12.190	10.518	9.250	8.254	7.452
	U	13.010	9.059	6.949	5.636	4.740	4.090	3.597	3.210	2.898
	Nb	51.029	35.350	27.041	21.895	18.394	15.858	13.937	12.431	11.219
	Ta	4.213	2.921	2.235	1.810	1.521	1.312	1.153	1.028	0.928
	La	30.533	29.208	27.994	26.876	25.844	24.889	24.002	23.175	22.404

	Ce	61.231	58.441	55.894	53.559	51.412	49.430	47.596	45.893	44.307
	Pb	14.450	13.561	12.776	12.076	11.449	10.884	10.372	9.906	9.480
	Pr	7.694	7.342	7.021	6.726	6.456	6.206	5.975	5.761	5.561
	Sr	104.813	109.800	115.284	121.345	128.078	135.603	144.067	153.658	164.617
	Nd	26.203	25.388	24.623	23.902	23.222	22.580	21.973	21.397	20.851
	Zr	881.107	612.351	469.227	380.332	319.755	275.823	242.505	216.369	195.318
	Hf	23.872	16.607	12.732	10.323	8.681	7.490	6.586	5.877	5.305
	Sm	5.048	4.931	4.820	4.713	4.611	4.514	4.420	4.331	4.244
	Eu	0.363	0.377	0.392	0.408	0.426	0.445	0.466	0.489	0.514
	Tb	0.794	0.766	0.740	0.716	0.693	0.672	0.652	0.633	0.615
	Dy	6.182	5.807	5.475	5.179	4.913	4.674	4.456	4.258	4.077
	Y	18.729	18.473	18.224	17.982	17.745	17.515	17.291	17.073	16.860
	Yb	4.372	3.911	3.538	3.230	2.971	2.750	2.560	2.395	2.250
	Lu	0.952	0.811	0.706	0.625	0.561	0.509	0.465	0.429	0.398
MS22	Element	Melt Fraction								
		0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70
	Rb	4.217	3.634	3.193	2.848	2.570	2.341	2.150	1.987	1.848
	Ba	111.558	98.472	88.134	79.760	72.840	67.024	62.068	57.795	54.072
	Th	0.422	0.364	0.320	0.285	0.257	0.234	0.215	0.199	0.185
	U	0.227	0.196	0.172	0.153	0.138	0.126	0.116	0.107	0.100
	Nb	4.172	3.620	3.196	2.862	2.591	2.366	2.178	2.017	1.878
	Ta	0.249	0.217	0.191	0.172	0.155	0.142	0.131	0.121	0.113
	La	10.403	9.564	8.851	8.236	7.702	7.232	6.817	6.446	6.114
	Ce	20.571	19.711	18.920	18.190	17.514	16.887	16.303	15.758	15.248
	Pb	1.271	1.125	1.008	0.914	0.836	0.770	0.713	0.665	0.622
	Pr	2.163	2.150	2.136	2.123	2.111	2.098	2.085	2.073	2.061
	Sr	333.016	332.355	331.697	331.042	330.389	329.739	329.091	328.446	327.804
	Nd	6.567	6.731	6.904	7.086	7.278	7.480	7.695	7.921	8.162
	Zr	88.434	80.776	74.339	68.852	64.120	59.996	56.370	53.158	50.292
	Hf	2.656	2.426	2.232	2.067	1.925	1.801	1.692	1.595	1.509
	Sm	1.103	1.155	1.212	1.276	1.346	1.425	1.513	1.613	1.727
	Eu	0.337	0.355	0.375	0.397	0.422	0.451	0.484	0.521	0.566
	Tb	0.152	0.160	0.169	0.180	0.191	0.205	0.220	0.238	0.259
	Dy	0.985	1.037	1.094	1.158	1.231	1.313	1.406	1.514	1.640
	Y	5.188	5.456	5.753	6.085	6.457	6.877	7.356	7.906	8.545
	Yb	0.601	0.628	0.659	0.692	0.729	0.770	0.816	0.867	0.926
	Lu	0.097	0.101	0.106	0.111	0.117	0.123	0.130	0.138	0.147
MS23	Element	Melt Fraction								
		0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50
	Rb	300.718	294.800	289.111	283.637	278.367	273.288	268.392	263.668	259.108
	Ba	995.996	1037.505	1082.624	1131.845	1185.756	1245.059	1310.606	1383.438	1464.841

	Th	2.845	1.999	1.541	1.253	1.056	0.913	0.804	0.718	0.648
	U	1.810	1.272	0.980	0.797	0.672	0.581	0.511	0.457	0.413
	Nb	9.916	9.829	9.744	9.661	9.578	9.498	9.418	9.340	9.264
	Ta	0.378	0.375	0.372	0.369	0.366	0.364	0.361	0.358	0.355
	La	10.011	9.518	9.071	8.664	8.292	7.951	7.637	7.346	7.077
	Ce	20.570	19.891	19.255	18.659	18.098	17.571	17.073	16.602	16.157
	Pb	18.078	15.968	14.299	12.945	11.826	10.885	10.082	9.390	8.787
	Pr	3.100	3.007	2.919	2.836	2.758	2.684	2.614	2.547	2.484
	Sr	97.668	100.646	103.812	107.183	110.781	114.629	118.754	123.187	127.963
	Nd	11.822	11.704	11.589	11.476	11.365	11.256	11.149	11.044	10.942
	Zr	461.891	361.502	296.960	251.973	218.823	193.382	173.240	156.898	143.373
	Hf	13.498	10.539	8.645	7.327	6.358	5.616	5.028	4.552	4.159
	Sm	3.127	3.132	3.136	3.141	3.145	3.150	3.154	3.159	3.164
	Eu	0.523	0.538	0.554	0.570	0.588	0.606	0.626	0.647	0.670
	Tb	0.874	0.868	0.862	0.857	0.851	0.846	0.840	0.835	0.830
	Dy	7.748	7.546	7.354	7.172	6.999	6.834	6.676	6.526	6.382
	Y	21.532	21.806	22.087	22.375	22.671	22.975	23.287	23.607	23.937
	Yb	5.219	4.954	4.715	4.498	4.300	4.119	3.952	3.798	3.656
	Lu	1.130	1.033	0.952	0.882	0.822	0.769	0.723	0.682	0.645
MS26	Element	Melt Fraction								
		0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90
	Rb	5.192	4.729	4.343	4.014	3.732	3.487	3.272	3.082	2.913
	Ba	92.331	84.225	77.428	71.646	66.667	62.335	58.532	55.166	52.167
	Th	1700.208	1548.397	1421.474	1313.782	1221.259	1140.911	1070.482	1008.243	952.843
	U	9.929	9.070	8.348	7.732	7.201	6.739	6.332	5.971	5.650
	Nb	3.543	3.237	2.979	2.759	2.570	2.405	2.260	2.131	2.016
	Ta	17.254	16.243	15.344	14.539	13.815	13.159	12.563	12.018	11.519
	La	1.173	1.109	1.052	1.001	0.954	0.911	0.872	0.837	0.804
	Ce	34.511	33.094	31.789	30.583	29.465	28.426	27.458	26.553	25.706
	Pb	56.832	55.932	55.059	54.213	53.393	52.597	51.825	51.075	50.347
	Pr	15.290	14.007	12.922	11.994	11.190	10.487	9.867	9.316	8.824
	Sr	5.851	5.890	5.929	5.968	6.008	6.049	6.090	6.132	6.174
	Nd	765.323	718.653	677.348	640.533	607.514	577.732	550.734	526.146	503.660
	Zr	16.790	17.400	18.056	18.763	19.528	20.358	21.261	22.249	23.332
	Hf	249.617	237.232	226.018	215.816	206.496	197.947	190.078	182.811	176.079
	Sm	6.605	6.271	5.969	5.695	5.445	5.216	5.006	4.812	4.632
	Eu	2.486	2.640	2.815	3.015	3.244	3.512	3.828	4.207	4.668
	Tb	0.636	0.679	0.729	0.787	0.855	0.936	1.033	1.153	1.305
	Dy	0.324	0.347	0.373	0.404	0.440	0.484	0.537	0.604	0.689
	Y	2.176	2.322	2.489	2.682	2.907	3.174	3.494	3.886	4.378
	Yb	11.146	11.911	12.788	13.806	14.999	16.418	18.133	20.249	22.924

	Lu	1.324	1.398	1.481	1.574	1.680	1.802	1.942	2.106	2.300
MS27	Element	Melt Fraction								
		0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75
	Rb	206.472	181.013	161.144	145.205	132.135	121.224	111.977	104.042	97.156
	Ba	5056.958	4432.979	3946.072	3555.541	3235.348	2968.061	2741.567	2547.190	2378.551
	Th	21.767	19.087	16.995	15.316	13.939	12.789	11.815	10.978	10.252
	U	6.724	5.896	5.250	4.731	4.306	3.951	3.650	3.391	3.167
	Nb	38.518	33.793	30.100	27.135	24.702	22.669	20.946	19.466	18.181
	Ta	2.675	2.347	2.091	1.885	1.716	1.575	1.455	1.353	1.263
	La	81.041	72.145	65.009	59.158	54.273	50.134	46.581	43.498	40.798
	Ce	167.290	149.764	135.562	123.820	113.950	105.537	98.282	91.959	86.401
	Pb	25.054	21.975	19.570	17.640	16.056	14.733	13.612	12.649	11.813
	Pr	20.812	18.663	16.916	15.468	14.249	13.208	12.308	11.524	10.833
	Sr	548.937	481.684	429.112	386.886	352.226	323.265	298.705	277.614	259.304
	Nd	79.846	72.228	65.937	60.655	56.156	52.278	48.901	45.934	43.307
	Zr	525.665	462.547	412.961	372.978	340.053	312.470	289.026	268.854	251.314
	Hf	13.939	12.265	10.951	9.890	9.017	8.286	7.664	7.129	6.664
	Sm	16.814	15.340	14.103	13.051	12.145	11.357	10.664	10.052	9.506
	Eu	4.396	4.038	3.735	3.474	3.247	3.048	2.872	2.715	2.575
	Tb	2.638	2.406	2.211	2.046	1.903	1.779	1.671	1.574	1.489
	Dy	16.322	14.882	13.676	12.651	11.768	11.001	10.328	9.732	9.201
	Y	68.259	64.206	60.607	57.390	54.497	51.882	49.506	47.339	45.353
	Yb	6.805	6.389	6.021	5.693	5.398	5.133	4.893	4.674	4.474
	Lu	1.141	1.065	0.998	0.939	0.886	0.839	0.797	0.759	0.725
MS28	Element	Melt Fraction								
		0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80
	Rb	366.923	327.697	296.048	269.974	248.122	229.542	213.550	199.642	187.435
	Ba	4330.965	4040.462	3786.481	3562.542	3363.612	3185.723	3025.705	2880.993	2749.492
	Th	10.563	9.436	8.526	7.776	7.147	6.612	6.152	5.752	5.401
	U	3.261	2.913	2.632	2.401	2.207	2.042	1.900	1.776	1.667
	Nb	31.135	28.365	26.047	24.080	22.389	20.920	19.631	18.493	17.479
	Ta	1.703	1.557	1.434	1.328	1.238	1.158	1.089	1.027	0.972
	La	37.534	35.810	34.237	32.797	31.473	30.252	29.122	28.073	27.097
	Ce	78.108	75.072	72.264	69.658	67.233	64.972	62.858	60.877	59.017
	Pb	17.100	15.861	14.789	13.853	13.028	12.296	11.642	11.054	10.522
	Pr	10.005	9.658	9.334	9.031	8.747	8.481	8.230	7.994	7.771
	Sr	129.519	135.239	141.487	148.341	155.892	164.254	173.564	183.992	195.753
	Nd	36.724	36.059	35.417	34.797	34.199	33.621	33.063	32.522	31.999
	Zr	402.212	365.872	335.554	309.877	287.850	268.747	252.021	237.255	224.124
	Hf	10.887	9.896	9.071	8.372	7.774	7.255	6.801	6.401	6.045

	Sm	7.683	7.660	7.636	7.613	7.590	7.567	7.544	7.521	7.499
	Eu	1.316	1.364	1.415	1.470	1.529	1.593	1.664	1.740	1.824
	Tb	1.369	1.365	1.362	1.358	1.354	1.350	1.347	1.343	1.339
	Dy	9.596	9.480	9.366	9.256	9.147	9.042	8.938	8.837	8.739
	Y	37.467	37.916	38.375	38.846	39.328	39.822	40.329	40.849	41.383
	Yb	4.904	4.833	4.764	4.697	4.632	4.569	4.507	4.447	4.389
	Lu	0.853	0.833	0.814	0.795	0.777	0.760	0.744	0.729	0.714
MS29	Element	Melt Fraction								
		0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80
	Rb	144.264	129.901	118.139	108.330	100.025	92.903	86.727	81.322	76.551
	Ba	1346.574	1295.229	1247.656	1203.454	1162.276	1123.824	1087.834	1054.078	1022.353
	Th	14.779	13.199	11.924	10.873	9.993	9.245	8.601	8.040	7.549
	U	4.800	4.287	3.873	3.532	3.246	3.003	2.794	2.612	2.452
	Nb	28.539	25.919	23.739	21.898	20.321	18.957	17.764	16.712	15.778
	Ta	1.908	1.735	1.591	1.470	1.365	1.274	1.195	1.125	1.063
	La	42.793	41.261	39.835	38.505	37.260	36.094	34.998	33.967	32.994
	Ce	80.613	78.737	76.945	75.234	73.597	72.029	70.528	69.087	67.704
	Pb	17.126	16.044	15.090	14.244	13.487	12.807	12.192	11.633	11.124
	Pr	9.079	8.984	8.892	8.801	8.712	8.625	8.539	8.455	8.373
	Sr	171.995	181.269	191.600	203.180	216.249	231.115	248.176	267.957	291.165
	Nd	28.243	28.609	28.985	29.370	29.766	30.173	30.591	31.021	31.463
	Zr	418.628	381.950	351.182	325.001	302.453	282.831	265.599	250.347	236.751
	Hf	11.156	10.176	9.354	8.655	8.053	7.530	7.070	6.664	6.301
	Sm	4.541	4.697	4.865	5.046	5.240	5.450	5.678	5.925	6.195
	Eu	0.825	0.871	0.923	0.982	1.048	1.124	1.212	1.314	1.436
	Tb	0.613	0.639	0.667	0.697	0.730	0.766	0.806	0.851	0.900
	Dy	4.210	4.360	4.522	4.696	4.883	5.087	5.308	5.549	5.813
	Y	19.385	20.192	21.069	22.025	23.073	24.226	25.499	26.914	28.496
	Yb	2.632	2.689	2.749	2.812	2.878	2.947	3.019	3.095	3.175
	Lu	0.454	0.462	0.470	0.478	0.486	0.495	0.504	0.513	0.523
MS30	Element	Melt Fraction								
		0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85
	Rb	74.517	67.144	61.098	56.052	51.775	48.105	44.921	42.132	39.669
	Ba	2875.793	2591.249	2357.944	2163.181	1998.137	1856.492	1733.600	1625.968	1530.919
	Th	7.993	7.202	6.553	6.012	5.553	5.160	4.818	4.519	4.255
	U	2.627	2.367	2.154	1.976	1.826	1.696	1.584	1.486	1.399
	Nb	9.274	8.356	7.604	6.976	6.443	5.987	5.590	5.243	4.937
	Ta	0.784	0.706	0.643	0.590	0.545	0.506	0.473	0.443	0.417
	La	24.902	22.512	20.540	18.885	17.478	16.265	15.210	14.284	13.463
	Ce	51.558	46.787	42.824	39.480	36.620	34.147	31.987	30.084	28.394
	Pb	6.889	6.212	5.657	5.193	4.799	4.461	4.167	3.910	3.682

	Pr	6.203	5.667	5.216	4.832	4.500	4.211	3.957	3.732	3.531
	Sr	314.843	284.718	259.854	238.985	221.218	205.910	192.584	180.877	170.513
	Nd	23.419	21.643	20.118	18.794	17.633	16.607	15.694	14.876	14.139
	Zr	144.015	130.560	119.405	110.006	101.979	95.043	88.991	83.664	78.938
	Hf	4.011	3.636	3.326	3.064	2.840	2.647	2.479	2.330	2.199
	Sm	4.895	4.616	4.367	4.144	3.942	3.759	3.592	3.440	3.299
	Eu	1.275	1.212	1.155	1.103	1.055	1.011	0.971	0.934	0.900
	Tb	0.821	0.786	0.754	0.724	0.696	0.671	0.647	0.625	0.604
	Dy	5.358	5.145	4.948	4.765	4.596	4.438	4.291	4.153	4.024
	Y	26.036	25.320	24.642	23.999	23.389	22.809	22.257	21.731	21.230
	Yb	2.543	2.501	2.459	2.419	2.380	2.343	2.306	2.271	2.237
	Lu	0.429	0.420	0.412	0.404	0.396	0.389	0.382	0.375	0.369
MS33	Element	Melt Fraction								
		0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75
	Rb	4.268	3.763	3.365	3.043	2.777	2.554	2.364	2.200	2.058
	Ba	148.056	139.124	131.209	124.146	117.804	112.079	106.884	102.150	97.817
	Th	0.427	0.375	0.335	0.302	0.276	0.253	0.234	0.218	0.204
	U	0.222	0.195	0.174	0.157	0.143	0.132	0.122	0.113	0.106
	Nb	1.507	1.484	1.461	1.439	1.418	1.397	1.377	1.358	1.339
	Ta	0.099	0.098	0.096	0.095	0.093	0.092	0.091	0.089	0.088
	La	5.688	5.492	5.309	5.138	4.978	4.827	4.685	4.551	4.425
	Ce	10.390	10.402	10.415	10.428	10.441	10.453	10.466	10.479	10.492
	Pb	1.567	1.406	1.275	1.167	1.075	0.997	0.930	0.871	0.819
	Pr	1.100	1.130	1.163	1.197	1.233	1.271	1.312	1.356	1.402
	Sr	190.750	195.195	199.852	204.736	209.866	215.259	220.937	226.922	233.241
	Nd	3.855	4.027	4.216	4.423	4.651	4.904	5.186	5.503	5.861
	Zr	55.806	54.443	53.145	51.907	50.725	49.597	48.517	47.483	46.493
	Hf	1.674	1.632	1.592	1.554	1.518	1.484	1.450	1.419	1.389
	Sm	0.666	0.708	0.754	0.808	0.869	0.941	1.026	1.127	1.251
	Eu	0.221	0.235	0.252	0.271	0.293	0.319	0.350	0.387	0.434
	Tb	0.110	0.118	0.126	0.136	0.147	0.161	0.177	0.196	0.221
	Dy	0.765	0.815	0.873	0.938	1.015	1.105	1.213	1.345	1.508
	Y	4.501	4.788	5.114	5.488	5.921	6.428	7.030	7.757	8.651
	Yb	0.557	0.590	0.627	0.670	0.718	0.775	0.841	0.919	1.013
	Lu	0.102	0.107	0.114	0.121	0.129	0.139	0.149	0.162	0.177
MS34	Element	Melt Fraction								
		0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80
	Rb	63.703	56.777	51.209	46.636	42.812	39.568	36.781	34.361	32.240
	Ba	1261.137	1123.757	1013.368	922.726	846.968	782.706	727.508	679.583	637.581
	Th	8.059	7.183	6.480	5.902	5.418	5.008	4.656	4.350	4.081
	U	2.757	2.457	2.217	2.019	1.853	1.713	1.593	1.488	1.396

		0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70
	Rb	209.370	210.152	210.939	211.732	212.531	213.336	214.147	214.964	215.788
	Ba	820.489	868.208	921.822	982.492	1051.712	1131.424	1224.210	1333.574	1464.395
	Th	1.018	0.884	0.782	0.701	0.635	0.580	0.534	0.495	0.461
	U	0.667	0.579	0.512	0.459	0.416	0.380	0.350	0.324	0.302
	Nb	7.028	7.119	7.212	7.308	7.406	7.507	7.611	7.718	7.827
	Ta	0.268	0.272	0.276	0.280	0.284	0.288	0.292	0.296	0.300
	La	5.452	5.432	5.412	5.392	5.372	5.352	5.333	5.313	5.294
	Ce	10.744	10.866	10.990	11.118	11.248	11.382	11.519	11.659	11.802
	Pb	12.010	11.031	10.199	9.484	8.862	8.317	7.836	7.407	7.022
	Pr	1.606	1.628	1.651	1.675	1.699	1.724	1.750	1.776	1.804
	Sr	147.409	150.587	153.906	157.374	161.002	164.801	168.784	172.964	177.357
	Nd	6.117	6.291	6.476	6.672	6.881	7.103	7.339	7.592	7.863
	Zr	201.34	180.372	163.36	149.28	137.434	127.33	118.611	111.008	104.322
	Hf	5.874	5.258	4.760	4.347	4.001	3.705	3.450	3.228	3.003
	Sm	1.612	1.672	1.736	1.805	1.880	1.961	2.050	2.147	2.254
	Eu	0.383	0.401	0.421	0.442	0.467	0.494	0.524	0.559	0.598
	Tb	0.408	0.422	0.437	0.454	0.472	0.491	0.512	0.535	0.560
	Dy	4.015	4.082	4.152	4.225	4.300	4.377	4.458	4.542	4.628
	Y	11.553	12.056	12.606	13.208	13.870	14.602	15.416	16.326	17.350
	Yb	3.143	3.103	3.064	3.026	2.989	2.953	2.918	2.883	2.850
	Lu	0.704	0.672	0.642	0.615	0.590	0.567	0.546	0.526	0.508
MS38	Element	Melt Fraction								
		0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70
	Rb	139.176	120.388	106.070	94.795	85.687	78.176	71.876	66.515	61.898
	Ba	1322.771	1251.089	1186.777	1128.753	1076.139	1028.211	984.370	944.115	907.023
	Th	12.096	10.453	9.203	8.220	7.427	6.774	6.226	5.760	5.359
	U	4.704	4.065	3.579	3.197	2.888	2.634	2.421	2.240	2.084
	Nb	17.736	15.401	13.610	12.191	11.041	10.089	9.288	8.604	8.015
	Ta	1.458	1.267	1.121	1.005	0.911	0.833	0.767	0.711	0.662
	La	23.454	22.810	22.200	21.622	21.074	20.553	20.056	19.584	19.133
	Ce	41.744	40.961	40.206	39.479	38.778	38.102	37.448	36.817	36.206
	Pb	13.076	12.227	11.481	10.821	10.233	9.706	9.230	8.799	8.406
	Pr	4.969	4.898	4.829	4.762	4.696	4.633	4.571	4.511	4.452
	Sr	170.973	180.000	190.034	201.253	213.879	228.196	244.567	263.468	285.536
	Nd	15.900	15.949	15.998	16.047	16.097	16.147	16.197	16.247	16.298
	Zr	298.075	260.639	231.557	208.313	189.310	173.485	160.101	148.634	138.700
	Hf	8.099	7.082	6.292	5.660	5.144	4.714	4.350	4.039	3.769
	Sm	2.742	2.787	2.833	2.881	2.931	2.982	3.035	3.090	3.147
	Eu	0.398	0.417	0.437	0.460	0.485	0.513	0.545	0.580	0.621
	Tb	0.379	0.385	0.391	0.397	0.404	0.410	0.417	0.424	0.431

	Dy	2.700	2.711	2.722	2.733	2.744	2.755	2.766	2.778	2.789
	Y	9.743	9.992	10.255	10.533	10.825	11.135	11.462	11.810	12.179
	Yb	1.634	1.615	1.596	1.577	1.559	1.542	1.525	1.508	1.492
	Lu	0.315	0.307	0.299	0.292	0.285	0.278	0.272	0.266	0.260
MS39	Element	Melt Fraction								
		0.70	0.75	0.80	0.85	0.90	0.95			
	Rb	62.125	58.046	54.47	51.309	48.494	45.972			
	Ba	1044.175	975.472	915.252	862.035	814.666	772.232			
	Th	5.371	5.019	4.71	4.437	4.194	3.976			
	U	2.089	1.952	1.832	1.726	1.631	1.546			
	Nb	7.941	7.447	7.011	6.623	6.276	5.963			
	Ta	0.655	0.615	0.579	0.547	0.519	0.493			
	La	22.112	21.008	20.009	19.1	18.27	17.51			
	Ce	38.886	37.748	36.675	35.661	34.702	33.793			
	Pb	9.341	8.745	8.221	7.756	7.34	6.967			
	Pr	4.166	4.16	4.154	4.148	4.142	4.136			
	Sr	743.067	708.297	676.635	647.682	621.106	596.625			
	Nd	12.971	13.463	13.993	14.567	15.19	15.868			
	Zr	129.19	122.941	117.269	112.098	107.363	103.012			
	Hf	3.513	3.342	3.188	3.047	2.918	2.799			
	Sm	1.904	2.063	2.251	2.476	2.752	3.097			
	Eu	0.512	0.56	0.619	0.692	0.785	0.905			
	Tb	0.209	0.231	0.258	0.292	0.335	0.395			
	Dy	1.331	1.461	1.62	1.817	2.068	2.401			
	Y	7.171	7.854	8.68	9.701	10.994	12.685			
	Yb	0.777	0.84	0.913	1	1.105	1.235			
	Lu	0.132	0.142	0.154	0.168	0.184	0.205			
MS40	Element	Melt Fraction								
		0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45
	Rb	20.674	11.586	8.048	6.166	4.997	4.200	3.623	3.185	2.842
	Ba	226.253	180.612	150.294	128.691	112.518	99.956	89.918	81.712	74.878
	Th	2.102	1.169	0.809	0.619	0.501	0.421	0.363	0.319	0.285
	U	1.132	0.629	0.436	0.333	0.270	0.227	0.195	0.172	0.153
	Nb	18.076	10.872	7.773	6.049	4.951	4.191	3.633	3.206	2.869
	Ta	1.052	0.642	0.462	0.361	0.296	0.251	0.218	0.192	0.172
	La	14.013	12.678	11.575	10.649	9.860	9.180	8.588	8.067	7.606
	Ce	23.149	22.199	21.325	20.516	19.767	19.070	18.421	17.815	17.247
	Pb	2.733	2.157	1.781	1.517	1.321	1.170	1.050	0.953	0.871
	Pr	2.195	2.184	2.172	2.160	2.149	2.137	2.126	2.115	2.104
	Sr	201.355	205.448	209.711	214.155	218.791	223.632	228.692	233.987	239.533
	Nd	6.035	6.163	6.297	6.437	6.583	6.736	6.896	7.064	7.240

	Zr	186.057	154.396	131.943	115.192	102.215	91.865	83.419	76.395	70.462
	Hf	5.594	4.640	3.964	3.460	3.069	2.758	2.504	2.293	2.115
	Sm	0.968	1.004	1.043	1.084	1.129	1.178	1.232	1.290	1.355
	Eu	0.270	0.282	0.294	0.308	0.322	0.339	0.357	0.376	0.399
	Tb	0.133	0.139	0.145	0.152	0.159	0.167	0.175	0.185	0.196
	Dy	0.880	0.915	0.954	0.995	1.040	1.090	1.144	1.204	1.271
	Y	4.481	4.660	4.854	5.065	5.295	5.547	5.824	6.130	6.470
	Yb	0.555	0.574	0.595	0.618	0.642	0.668	0.696	0.727	0.761
	Lu	0.091	0.094	0.097	0.101	0.105	0.109	0.113	0.118	0.123
MS41	Element	Melt Fraction								
		0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	
	Rb	20.871	11.645	8.075	6.18	5.006	4.206	3.627	3.188	
	Ba	234.079	185.297	153.341	130.785	114.015	101.056	90.743	82.339	
	Th	2.019	1.144	0.798	0.613	0.497	0.419	0.361	0.318	
	U	1.087	0.616	0.43	0.33	0.268	0.225	0.195	0.171	
	Nb	17.520	10.678	7.680	5.996	4.918	4.168	3.617	3.194	
	Ta	1.006	0.625	0.453	0.356	0.293	0.249	0.216	0.191	
	La	10.552	9.896	9.316	8.801	8.340	7.925	7.549	7.207	
	Ce	17.949	17.574	17.214	16.869	16.537	16.218	15.911	15.616	
	Pb	2.803	2.198	1.808	1.535	1.334	1.180	1.057	0.958	
	Pr	1.841	1.848	1.856	1.863	1.871	1.878	1.886	1.893	
	Sr	210.401	214.357	218.464	222.731	227.169	231.787	236.597	241.611	
	Nd	5.219	5.354	5.495	5.644	5.802	5.969	6.145	6.332	
	Zr	181.875	151.654	130.046	113.827	101.205	91.103	82.835	75.942	
	Hf	5.465	4.555	3.905	3.418	3.038	2.735	2.486	2.279	
	Sm	0.872	0.906	0.942	0.982	1.025	1.072	1.123	1.180	
	Eu	0.248	0.259	0.271	0.283	0.297	0.313	0.330	0.349	
	Tb	0.124	0.129	0.135	0.141	0.148	0.156	0.164	0.174	
	Dy	0.830	0.864	0.901	0.941	0.985	1.033	1.086	1.145	
	Y	4.018	4.184	4.366	4.564	4.780	5.019	5.282	5.574	
	Yb	0.531	0.550	0.571	0.593	0.617	0.642	0.671	0.701	
	Lu	0.088	0.091	0.095	0.098	0.102	0.106	0.110	0.115	
MS43	Element	Melt Fraction								
		0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75
	Rb	381.918	335.118	298.536	269.155	245.038	224.888	207.800	193.126	180.387
	Ba	5611.690	5041.245	4576.074	4189.496	3863.145	3583.964	3342.414	3131.369	2945.392
	Th	9.489	8.329	7.421	6.692	6.093	5.592	5.168	4.803	4.487
	U	3.346	2.937	2.617	2.359	2.148	1.972	1.822	1.694	1.582
	Nb	24.964	23.070	21.443	20.030	18.792	17.698	16.725	15.853	15.067
	Ta	1.396	1.290	1.199	1.120	1.050	0.989	0.935	0.886	0.842
	La	31.645	29.974	28.471	27.112	25.876	24.748	23.715	22.764	21.887

	Ce	53.344	51.856	50.449	49.117	47.853	46.653	45.511	44.424	43.387
	Pb	20.107	17.734	15.862	14.348	13.097	12.047	11.153	10.383	9.712
	Pr	5.882	5.822	5.764	5.706	5.650	5.595	5.541	5.488	5.436
	Sr	432.513	415.372	399.538	384.867	371.235	358.536	346.677	335.577	325.166
	Nd	19.325	19.540	19.760	19.985	20.215	20.450	20.691	20.937	21.190
	Zr	330.539	303.453	280.469	260.723	243.573	228.541	215.256	203.431	192.837
	Hf	8.834	8.107	7.491	6.962	6.503	6.100	5.745	5.428	5.145
	Sm	3.296	3.410	3.532	3.662	3.803	3.955	4.120	4.299	4.494
	Eu	0.856	0.891	0.929	0.970	1.016	1.065	1.120	1.181	1.249
	Tb	0.549	0.571	0.595	0.621	0.650	0.681	0.716	0.754	0.797
	Dy	3.841	3.980	4.130	4.291	4.466	4.655	4.861	5.086	5.333
	Y	19.102	19.853	20.665	21.546	22.506	23.555	24.707	25.978	27.386
	Yb	2.482	2.537	2.594	2.654	2.717	2.782	2.851	2.924	3.000
	Lu	0.455	0.461	0.467	0.473	0.479	0.486	0.492	0.499	0.506
MS44	Element	Melt Fraction								
		0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95
	Rb	85.258	78.202	72.224	67.096	62.647	58.752	55.313	52.254	49.516
	Ba	1547.948	1421.137	1313.531	1221.073	1140.775	1070.386	1008.179	952.805	903.198
	Th	9.222	8.462	7.818	7.265	6.785	6.364	5.993	5.662	5.367
	U	3.291	3.020	2.790	2.593	2.421	2.271	2.139	2.021	1.915
	Nb	19.007	17.479	16.177	15.056	14.081	13.224	12.465	11.789	11.182
	Ta	1.332	1.224	1.133	1.055	0.986	0.926	0.873	0.826	0.783
	La	36.201	34.303	32.594	31.047	29.640	28.355	27.177	26.093	25.092
	Ce	66.404	63.874	61.529	59.350	57.320	55.425	53.651	51.987	50.423
	Pb	14.413	13.228	12.224	11.360	10.611	9.955	9.375	8.859	8.396
	Pr	7.885	7.664	7.455	7.257	7.069	6.891	6.722	6.560	6.407
	Sr	783.473	727.795	679.506	637.226	599.899	566.703	536.988	510.235	486.020
	Nd	27.230	27.069	26.911	26.754	26.599	26.446	26.294	26.144	25.996
	Zr	285.819	264.028	245.324	229.095	214.880	202.326	191.158	181.158	172.153
	Hf	7.510	6.938	6.446	6.020	5.647	5.317	5.023	4.761	4.524
	Sm	4.998	5.090	5.187	5.287	5.391	5.499	5.612	5.730	5.852
	Eu	1.337	1.374	1.414	1.456	1.500	1.547	1.598	1.651	1.709
	Tb	0.743	0.762	0.782	0.804	0.826	0.850	0.875	0.902	0.930
	Dy	4.979	5.064	5.151	5.242	5.336	5.433	5.534	5.638	5.747
	Y	23.394	24.060	24.765	25.513	26.307	27.152	28.053	29.016	30.047
	Yb	2.860	2.855	2.851	2.846	2.842	2.837	2.833	2.829	2.824
	Lu	0.489	0.484	0.480	0.475	0.471	0.466	0.462	0.458	0.454
MS45	Element	Melt Fraction								
		0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75
	Rb	190.693	169.653	152.794	138.983	127.462	117.705	109.335	102.077	95.722
	Ba	3361.918	3148.471	2960.509	2793.726	2644.732	2510.826	2389.826	2279.952	2179.737

	Th	21.781	19.097	17.002	15.321	13.943	12.792	11.817	10.980	10.254
	U	6.728	5.899	5.252	4.733	4.307	3.951	3.650	3.392	3.167
	Nb	35.050	31.286	28.252	25.755	23.663	21.885	20.356	19.027	17.860
	Ta	2.432	2.171	1.961	1.788	1.643	1.520	1.414	1.322	1.241
	La	84.149	74.404	66.682	60.411	55.219	50.849	47.119	43.900	41.092
	Ce	181.846	160.372	143.434	129.732	118.420	108.922	100.835	93.865	87.797
	Pb	23.522	20.874	18.762	17.039	15.605	14.394	13.357	12.460	11.675
	Pr	22.851	20.151	18.022	16.300	14.878	13.685	12.668	11.792	11.030
	Sr	291.626	280.918	270.969	261.700	253.045	244.944	237.345	230.204	223.479
	Nd	92.470	81.522	72.891	65.913	60.154	55.321	51.207	47.662	44.576
	Zr	523.428	460.946	411.791	372.109	339.403	311.982	288.660	268.583	251.117
	Hf	13.886	12.228	10.923	9.870	9.002	8.274	7.656	7.123	6.659
	Sm	20.451	18.042	16.141	14.602	13.331	12.263	11.354	10.571	9.888
	Eu	4.142	3.839	3.578	3.349	3.149	2.970	2.811	2.669	2.540
	Tb	3.124	2.769	2.486	2.255	2.064	1.902	1.764	1.645	1.541
	Dy	18.439	16.475	14.888	13.580	12.484	11.551	10.748	10.050	9.436
	Y	85.933	78.164	71.683	66.195	61.487	57.404	53.830	50.675	47.869
	Yb	7.423	6.886	6.421	6.015	5.657	5.340	5.056	4.801	4.570
	Lu	1.212	1.121	1.043	0.975	0.915	0.862	0.815	0.773	0.735
MS46	Element	Melt Fraction								
		0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80
	Rb	161.199	160.259	159.330	158.411	157.504	156.606	155.719	154.842	153.975
	Ba	712.392	756.094	805.508	861.833	926.627	1001.955	1090.615	1196.488	1325.126
	Th	10.460	9.360	8.470	7.734	7.116	6.589	6.135	5.739	5.392
	U	3.230	2.890	2.615	2.388	2.197	2.034	1.894	1.772	1.665
	Nb	12.828	12.942	13.057	13.175	13.294	13.416	13.540	13.666	13.795
	Ta	0.703	0.710	0.718	0.725	0.733	0.741	0.749	0.757	0.765
	La	37.312	35.625	34.084	32.670	31.369	30.168	29.055	28.021	27.059
	Ce	75.163	72.567	70.145	67.879	65.755	63.760	61.882	60.112	58.440
	Pb	16.970	15.758	14.708	13.788	12.977	12.257	11.612	11.031	10.506
	Pr	9.759	9.447	9.154	8.879	8.621	8.376	8.146	7.927	7.720
	Sr	193.209	197.578	202.149	206.937	211.958	217.227	222.766	228.594	234.736
	Nd	35.782	35.224	34.683	34.158	33.649	33.155	32.675	32.209	31.756
	Zr	364.228	336.601	312.871	292.265	274.207	258.249	244.048	231.326	219.865
	Hf	9.906	9.142	8.487	7.920	7.424	6.986	6.597	6.249	5.936
	Sm	7.714	7.688	7.662	7.636	7.610	7.584	7.559	7.534	7.509
	Eu	1.602	1.642	1.684	1.728	1.774	1.823	1.875	1.930	1.988
	Tb	1.471	1.458	1.445	1.432	1.419	1.407	1.394	1.382	1.370
	Dy	10.852	10.589	10.340	10.101	9.873	9.656	9.448	9.248	9.057
	Y	39.882	40.172	40.466	40.765	41.068	41.376	41.688	42.005	42.327

	Yb	6.578	6.276	6.000	5.748	5.516	5.302	5.104	4.920	4.750
	Lu	1.177	1.105	1.041	0.984	0.933	0.887	0.846	0.808	0.773
MS47	Element	Melt Fraction								
		0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90
	Rb	121.257	110.679	101.798	94.237	87.721	82.048	77.064	72.651	68.716
	Ba	1720.089	1580.234	1461.411	1359.208	1270.365	1192.424	1123.494	1062.098	1007.064
	Th	11.664	10.678	9.846	9.134	8.518	7.980	7.506	7.085	6.709
	U	3.789	3.468	3.198	2.967	2.767	2.592	2.438	2.301	2.179
	Nb	22.811	21.182	19.770	18.535	17.445	16.476	15.609	14.829	14.123
	Ta	1.539	1.429	1.334	1.251	1.177	1.112	1.053	1.000	0.953
	La	22.493	23.046	23.628	24.240	24.884	25.563	26.281	27.040	27.844
	Ce	35.804	37.408	39.163	41.090	43.217	45.576	48.207	51.162	54.501
	Pb	18.234	16.688	15.384	14.268	13.304	12.461	11.719	11.061	10.472
	Pr	3.959	4.171	4.407	4.672	4.971	5.310	5.699	6.149	6.677
	Sr	601.900	581.486	562.412	544.548	527.785	512.023	497.175	483.164	469.921
	Nd	11.432	12.237	13.163	14.240	15.511	17.029	18.878	21.177	24.113
	Zr	313.170	295.161	279.111	264.717	251.734	239.965	229.248	219.447	210.449
	Hf	8.32	7.843	7.418	7.037	6.693	6.381	6.097	5.837	5.598
	Sm	1.799	1.948	2.123	2.333	2.589	2.908	3.317	3.859	4.613
	Eu	0.462	0.502	0.55	0.607	0.678	0.768	0.886	1.045	1.276
	Tb	0.261	0.282	0.309	0.34	0.378	0.426	0.489	0.572	0.69
	Dy	1.893	2.043	2.22	2.43	2.683	2.996	3.391	3.906	4.607
	Y	7.454	8.102	8.873	9.807	10.961	12.422	14.332	16.938	20.7
	Yb	1.308	1.396	1.497	1.613	1.749	1.91	2.104	2.342	2.639
	Lu	0.248	0.263	0.279	0.298	0.32	0.345	0.374	0.408	0.45
MS48	Element	Melt Fraction								
		0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90
	Rb	140.093	128.301	118.340	109.814	102.435	95.984	90.298	85.248	80.733
	Ba	2973.230	2788.149	2624.761	2479.462	2349.405	2232.313	2126.338	2029.969	1941.957
	Th	15.325	13.946	12.795	11.819	10.981	10.254	9.618	9.056	8.556
	U	4.734	4.308	3.952	3.651	3.392	3.167	2.971	2.797	2.643
	Nb	25.910	23.781	21.975	20.424	19.077	17.897	16.855	15.927	15.096
	Ta	1.798	1.651	1.526	1.418	1.325	1.243	1.171	1.107	1.049
	La	61.742	56.216	51.597	47.680	44.316	41.395	38.836	36.574	34.562
	Ce	131.593	119.811	109.966	101.616	94.445	88.219	82.763	77.943	73.653
	Pb	17.562	15.998	14.690	13.579	12.625	11.796	11.069	10.426	9.854
	Pr	16.503	15.030	13.799	12.754	11.856	11.076	10.392	9.788	9.251
	Sr	382.034	348.598	320.544	296.669	276.104	258.205	242.486	228.571	216.166
	Nd	66.558	60.637	55.683	51.478	47.863	44.723	41.969	39.535	37.367
	Zr	371.095	338.643	311.411	288.232	268.265	250.885	235.620	222.106	210.058
	Hf	9.844	8.982	8.260	7.645	7.115	6.654	6.249	5.890	5.570

	Sm	14.667	13.380	12.300	11.382	10.591	9.903	9.299	8.764	8.288
	Eu	3.969	3.627	3.340	3.095	2.884	2.699	2.537	2.393	2.265
	Tb	2.253	2.062	1.901	1.764	1.644	1.540	1.449	1.367	1.294
	Dy	13.475	12.403	11.490	10.702	10.015	9.411	8.875	8.398	7.969
	Y	64.760	60.369	56.535	53.160	50.164	47.489	45.084	42.911	40.938
	Yb	5.789	5.476	5.195	4.942	4.713	4.503	4.312	4.136	3.974
	Lu	0.941	0.888	0.841	0.798	0.760	0.725	0.693	0.664	0.638
MS49	Element	Melt Fraction								
		0.75	0.80	0.85	0.90	0.95				
	Rb	96.911	90.953	85.685	80.994	76.789				
	Ba	2378.792	2231.025	2100.542	1984.478	1880.569				
	Th	10.210	9.587	9.035	8.544	8.103				
	U	3.154	2.961	2.791	2.639	2.503				
	Nb	16.970	16.188	15.476	14.823	14.223				
	Ta	1.166	1.115	1.069	1.026	0.987				
	La	40.860	38.458	36.322	34.411	32.691				
	Ce	87.179	82.029	77.453	73.361	69.680				
	Pb	11.741	11.030	10.401	9.839	9.335				
	Pr	10.957	10.308	9.732	9.217	8.754				
	Sr	259.293	243.252	229.081	216.470	205.175				
	Nd	44.263	41.644	39.318	37.238	35.367				
	Zr	239.168	227.255	216.473	206.667	197.712				
	Hf	6.360	6.039	5.749	5.486	5.245				
	Sm	9.797	9.224	8.714	8.258	7.847				
	Eu	2.663	2.511	2.376	2.254	2.145				
	Tb	1.516	1.432	1.356	1.288	1.226				
	Dy	9.153	8.691	8.273	7.893	7.547				
	Y	44.972	43.246	41.647	40.163	38.780				
	Yb	4.125	4.029	3.937	3.849	3.765				
	Lu	0.668	0.650	0.634	0.619	0.604				
MS50	Element	Melt Fraction								
		0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85
	Rb	128.014	115.373	105.004	96.345	89.006	82.705	77.238	72.448	68.218
	Ba	3674.545	3334.890	3052.714	2814.564	2610.883	2434.692	2280.777	2145.166	2024.776
	Th	14.879	13.407	12.200	11.193	10.339	9.606	8.970	8.414	7.922
	U	4.923	4.436	4.037	3.703	3.421	3.178	2.968	2.784	2.621
	Nb	22.807	20.908	19.301	17.924	16.730	15.685	14.763	13.944	13.210
	Ta	1.649	1.512	1.396	1.296	1.210	1.134	1.067	1.008	0.955
	La	53.797	48.932	44.874	41.437	38.490	35.934	33.696	31.720	29.964
	Ce	105.920	96.988	89.444	82.990	77.404	72.523	68.221	64.400	60.985
	Pb	16.170	14.596	13.301	12.217	11.296	10.504	9.816	9.213	8.680

	Pr	12.409	11.472	10.666	9.966	9.352	8.810	8.327	7.894	7.504
	Sr	389.025	361.972	338.436	317.774	299.490	283.196	268.583	255.404	243.458
	Nd	47.412	44.152	41.310	38.813	36.600	34.626	32.854	31.254	29.803
	Zr	324.683	296.587	272.967	252.831	235.462	220.326	207.018	195.226	184.706
	Hf	8.503	7.766	7.147	6.619	6.163	5.767	5.418	5.109	4.833
	Sm	9.015	8.598	8.219	7.871	7.551	7.257	6.984	6.731	6.496
	Eu	2.207	2.123	2.045	1.972	1.904	1.841	1.782	1.726	1.674
	Tb	1.341	1.293	1.249	1.208	1.169	1.133	1.099	1.067	1.036
	Dy	8.154	7.882	7.627	7.389	7.165	6.954	6.755	6.567	6.389
	Y	42.388	41.081	39.851	38.693	37.601	36.568	35.591	34.664	33.785
	Yb	3.797	3.702	3.613	3.527	3.445	3.367	3.293	3.222	3.153
	Lu	0.650	0.629	0.609	0.591	0.573	0.557	0.541	0.527	0.513
MS51	Element	Melt Fraction								
		0.75	0.80	0.85	0.90	0.95				
	Rb	77.190	72.415	68.196	64.441	61.079				
	Ba	2244.413	2119.329	2007.451	1906.793	1815.747				
	Th	8.969	8.412	7.921	7.484	7.092				
	U	2.967	2.783	2.621	2.476	2.347				
	Nb	14.194	13.533	12.932	12.381	11.876				
	Ta	1.026	0.979	0.935	0.895	0.859				
	La	33.009	31.231	29.635	28.194	26.887				
	Ce	65.804	62.663	59.807	57.201	54.812				
	Pb	9.782	9.189	8.663	8.195	7.774				
	Pr	7.852	7.548	7.266	7.005	6.762				
	Sr	249.024	241.004	233.484	226.420	219.770				
	Nd	30.429	29.467	28.564	27.715	26.915				
	Zr	201.192	191.053	181.886	173.559	165.961				
	Hf	5.267	5.001	4.761	4.542	4.343				
	Sm	6.065	6.027	5.990	5.953	5.916				
	Eu	1.511	1.516	1.521	1.525	1.530				
	Tb	0.925	0.931	0.937	0.943	0.949				
	Dy	5.686	5.730	5.774	5.818	5.864				
	Y	30.176	30.412	30.652	30.896	31.143				
	Yb	2.791	2.824	2.858	2.893	2.928				
	Lu	0.470	0.471	0.472	0.473	0.474				
MS52	Element	Melt Fraction								
		0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85
	Rb	73.964	66.735	60.794	55.824	51.605	47.979	44.829	42.067	39.626
	Ba	2379.345	2213.016	2068.422	1941.565	1829.369	1729.431	1639.847	1559.086	1485.907
	Th	7.967	7.183	6.539	6.001	5.545	5.154	4.814	4.516	4.253
	U	2.619	2.361	2.150	1.973	1.823	1.694	1.582	1.485	1.398

		0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70
	Rb	422.038	380.193	345.897	317.277	293.031	272.227	254.182	238.380	224.428
	Ba	3519.827	3445.117	3373.513	3304.824	3238.877	3175.510	3114.575	3055.934	2999.461
	Th	0.941	0.811	0.713	0.636	0.574	0.523	0.480	0.444	0.413
	U	0.594	0.512	0.450	0.401	0.362	0.330	0.303	0.280	0.260
	Nb	14.827	13.648	12.642	11.775	11.019	10.354	9.765	9.239	8.767
	Ta	0.580	0.536	0.497	0.464	0.435	0.409	0.387	0.366	0.348
	La	12.077	10.845	9.840	9.007	8.303	7.701	7.181	6.726	6.326
	Ce	23.473	21.884	20.497	19.276	18.192	17.223	16.352	15.565	14.851
	Pb	12.894	11.242	9.966	8.949	8.121	7.433	6.853	6.357	5.927
	Pr	2.703	2.615	2.533	2.456	2.384	2.315	2.251	2.190	2.132
	Sr	492.466	449.764	413.876	383.292	356.917	333.938	313.739	295.844	279.881
	Nd	8.901	8.932	8.963	8.994	9.026	9.057	9.089	9.121	9.153
	Zr	165.394	150.378	137.861	127.268	118.187	110.315	103.427	97.348	91.944
	Hf	4.849	4.405	4.036	3.724	3.456	3.225	3.022	2.844	2.685
	Sm	1.698	1.754	1.813	1.876	1.944	2.017	2.095	2.180	2.273
	Eu	0.490	0.509	0.530	0.552	0.577	0.603	0.632	0.664	0.700
	Tb	0.315	0.328	0.343	0.359	0.377	0.396	0.418	0.442	0.469
	Dy	2.288	2.380	2.481	2.590	2.709	2.840	2.984	3.143	3.321
	Y	12.395	12.892	13.431	14.016	14.655	15.355	16.124	16.976	17.922
	Yb	1.413	1.461	1.514	1.570	1.630	1.695	1.765	1.842	1.925
	Lu	0.235	0.243	0.251	0.259	0.269	0.279	0.290	0.301	0.314
MS57	Element	Melt Fraction								
		0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80
	Rb	3.827	3.411	3.077	2.803	2.573	2.378	2.211	2.066	1.938
	Ba	199.230	177.504	160.051	145.723	133.750	123.594	114.872	107.300	100.665
	Th	0.377	0.336	0.303	0.276	0.254	0.235	0.218	0.204	0.191
	U	0.196	0.175	0.158	0.144	0.132	0.122	0.113	0.106	0.099
	Nb	2.859	2.582	2.355	2.164	2.002	1.862	1.741	1.634	1.540
	Ta	0.186	0.168	0.154	0.141	0.131	0.122	0.114	0.107	0.101
	La	7.923	7.291	6.753	6.289	5.885	5.529	5.214	4.933	4.680
	Ce	17.194	16.338	15.563	14.859	14.215	13.625	13.082	12.580	12.116
	Pb	1.513	1.355	1.227	1.121	1.032	0.956	0.890	0.833	0.783
	Pr	2.063	2.026	1.990	1.956	1.923	1.891	1.860	1.830	1.801
	Sr	536.574	496.053	461.223	430.963	404.430	380.974	360.089	341.376	324.511
	Nd	7.034	7.147	7.264	7.385	7.510	7.639	7.773	7.912	8.055
	Zr	82.619	76.485	71.199	66.596	62.552	58.972	55.779	52.914	50.329
	Hf	2.469	2.285	2.126	1.988	1.867	1.760	1.664	1.578	1.501
	Sm	1.341	1.401	1.467	1.540	1.620	1.708	1.807	1.918	2.044
	Eu	0.453	0.476	0.502	0.530	0.562	0.598	0.639	0.687	0.741
	Tb	0.219	0.231	0.245	0.260	0.277	0.297	0.320	0.346	0.378

	Dy	1.534	1.615	1.705	1.805	1.918	2.045	2.192	2.360	2.557
	Y	8.327	8.759	9.239	9.774	10.375	11.055	11.830	12.722	13.759
	Yb	0.995	1.040	1.090	1.144	1.204	1.271	1.345	1.429	1.524
	Lu	0.166	0.173	0.181	0.189	0.199	0.209	0.221	0.234	0.248
MS58	Element	Melt Fraction								
		0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95	
	Rb	55.988	51.734	48.080	44.909	42.130	39.674	37.490	35.533	
	Ba	2159.714	1995.599	1854.665	1732.324	1625.124	1530.418	1446.143	1370.665	
	Th	6.003	5.547	5.155	4.815	4.517	4.254	4.020	3.810	
	U	1.973	1.823	1.695	1.583	1.485	1.398	1.321	1.252	
	Nb	6.968	6.438	5.983	5.588	5.242	4.937	4.665	4.421	
	Ta	0.589	0.544	0.506	0.472	0.443	0.417	0.394	0.374	
	La	17.711	16.587	15.598	14.719	13.934	13.229	12.592	12.013	
	Ce	33.811	32.234	30.797	29.483	28.276	27.165	26.137	25.184	
	Pb	5.151	4.767	4.437	4.150	3.897	3.674	3.474	3.296	
	Pr	3.635	3.549	3.466	3.387	3.312	3.240	3.171	3.105	
	Sr	220.155	206.826	195.020	184.488	175.036	166.505	158.767	151.716	
	Nd	11.490	11.586	11.684	11.784	11.885	11.989	12.094	12.200	
	Zr	103.382	96.910	91.201	86.127	81.588	77.503	73.808	70.449	
	Hf	2.883	2.703	2.544	2.402	2.275	2.162	2.058	1.965	
	Sm	1.904	1.992	2.088	2.194	2.311	2.441	2.587	2.751	
	Eu	0.468	0.494	0.523	0.556	0.594	0.636	0.686	0.743	
	Tb	0.290	0.309	0.329	0.353	0.381	0.413	0.451	0.496	
	Dy	2.046	2.166	2.302	2.455	2.630	2.833	3.069	3.348	
	Y	11.095	11.742	12.470	13.294	14.235	15.319	16.582	18.072	
	Yb	1.333	1.399	1.472	1.553	1.643	1.745	1.859	1.990	
	Lu	0.225	0.235	0.247	0.259	0.273	0.289	0.306	0.326	
MS59	Element	Melt Fraction								
		0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85
	Rb	103.472	93.300	84.950	77.971	72.052	66.968	62.555	58.687	55.269
	Ba	1887.999	1702.408	1550.039	1422.704	1314.701	1221.940	1141.406	1070.830	1008.475
	Th	11.216	10.113	9.208	8.452	7.810	7.259	6.781	6.361	5.991
	U	4.003	3.609	3.286	3.016	2.787	2.590	2.420	2.270	2.138
	Nb	23.409	21.104	19.213	17.633	16.293	15.142	14.143	13.268	12.494
	Ta	1.640	1.478	1.346	1.235	1.141	1.061	0.991	0.929	0.875
	La	45.582	42.183	39.256	36.709	34.472	32.492	30.728	29.145	27.717
	Ce	75.540	71.985	68.750	65.793	63.080	60.582	58.274	56.135	54.148
	Pb	17.228	15.586	14.230	13.091	12.120	11.284	10.556	9.916	9.349
	Pr	7.406	7.285	7.168	7.054	6.944	6.837	6.734	6.633	6.536
	Sr	844.448	785.870	734.892	690.124	650.498	615.175	583.491	554.910	528.999
	Nd	20.866	21.238	21.624	22.024	22.439	22.870	23.318	23.784	24.269

	Zr	307.527	284.864	265.311	248.270	233.286	220.008	208.160	197.522	187.919	
	Hf	8.082	7.486	6.972	6.525	6.131	5.782	5.471	5.191	4.939	
	Sm	2.949	3.092	3.248	3.422	3.615	3.832	4.076	4.353	4.671	
	Eu	0.755	0.796	0.843	0.895	0.954	1.021	1.098	1.189	1.295	
	Tb	0.366	0.388	0.412	0.440	0.472	0.509	0.552	0.603	0.665	
	Dy	2.399	2.535	2.688	2.860	3.055	3.280	3.539	3.844	4.205	
	Y	12.989	13.716	14.529	15.445	16.484	17.673	19.047	20.652	22.553	
	Yb	1.374	1.441	1.515	1.597	1.689	1.791	1.907	2.039	2.191	
	Lu	0.229	0.240	0.251	0.264	0.279	0.295	0.313	0.333	0.356	
MS60	Element	Melt Fraction									
		0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55
	Rb	270.623	230.655	200.973	178.060	159.836	144.997	132.679	122.289	113.409	105.731
	Ba	2942.088	2912.175	2882.863	2854.136	2825.976	2798.367	2771.291	2744.734	2718.682	2693.119
	Th	67.560	45.770	34.608	27.823	23.262	19.986	17.519	15.594	14.050	12.784
	U	21.914	14.846	11.225	9.025	7.545	6.483	5.682	5.058	4.557	4.147
	Nb	27.672	23.916	21.057	18.809	16.994	15.499	14.246	13.180	12.263	11.465
	Ta	2.411	2.084	1.835	1.639	1.481	1.351	1.241	1.148	1.069	0.999
	La	189.306	128.453	97.206	78.187	65.392	56.196	49.268	43.860	39.522	35.965
	Ce	383.566	260.268	196.956	158.420	132.495	113.863	99.824	88.868	80.078	72.871
	Pb	45.591	32.372	25.096	20.490	17.313	14.989	13.215	11.816	10.685	9.752
	Pr	44.587	30.255	22.895	18.415	15.402	13.236	11.604	10.330	9.309	8.471
	Sr	457.590	353.983	288.632	243.650	210.798	185.753	166.027	150.088	136.942	125.913
	Nd	164.154	111.386	84.291	67.799	56.704	48.730	42.722	38.033	34.271	31.187
	Zr	819.053	562.647	428.503	346.009	290.151	249.820	219.334	195.478	176.303	160.554
	Hf	21.995	15.109	11.507	9.292	7.792	6.709	5.890	5.249	4.734	4.312
	Sm	31.821	21.592	16.340	13.143	10.992	9.446	8.282	7.373	6.643	6.045
	Eu	5.089	3.595	2.779	2.265	1.911	1.653	1.457	1.302	1.177	1.073
	Tb	4.458	3.030	2.295	1.847	1.545	1.328	1.164	1.037	0.934	0.850
	Dy	27.954	19.028	14.423	11.612	9.718	8.356	7.328	6.526	5.882	5.353
	Y	144.834	98.892	75.077	60.506	50.672	43.587	38.241	34.063	30.708	27.954
	Yb	15.686	10.743	8.169	6.590	5.523	4.753	4.171	3.717	3.351	3.051
	Lu	2.577	1.770	1.348	1.089	0.913	0.786	0.690	0.615	0.555	0.505
MS62	Element	Melt Fraction									
		0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	
	Rb	116.782	107.702	99.931	93.207	87.330	82.151	77.551	73.439	69.742	
	Ba	458.886	488.836	522.967	562.224	607.851	661.539	725.630	803.471	900.020	
	Th	16.237	14.530	13.149	12.007	11.048	10.230	9.526	8.912	8.372	
	U	5.220	4.696	4.267	3.910	3.608	3.349	3.125	2.929	2.756	
	Nb	27.343	24.493	22.181	20.268	18.658	17.286	16.101	15.069	14.160	
	Ta	1.944	1.747	1.586	1.452	1.339	1.242	1.158	1.085	1.021	
	La	54.985	50.215	46.207	42.791	39.845	37.279	35.023	33.025	31.243	

	Ce	122.453	110.258	100.271	91.943	84.893	78.846	73.604	69.016	64.966
	Pb	9.403	9.195	8.996	8.805	8.622	8.447	8.279	8.117	7.962
	Pr	15.418	13.849	12.570	11.507	10.610	9.843	9.179	8.599	8.088
	Sr	35.049	37.673	40.722	44.307	48.585	53.778	60.213	68.398	79.157
	Nd	62.647	56.124	50.831	46.450	42.765	39.621	36.908	34.543	32.462
	Zr	382.523	342.410	309.911	283.046	260.468	241.225	224.630	210.171	197.462
	Hf	9.940	8.908	8.071	7.377	6.794	6.295	5.865	5.490	5.160
	Sm	14.330	12.798	11.561	10.543	9.689	8.963	8.339	7.795	7.319
	Eu	0.570	0.602	0.637	0.677	0.721	0.773	0.832	0.900	0.982
	Tb	2.317	2.071	1.872	1.708	1.570	1.453	1.352	1.265	1.188
	Dy	14.337	12.814	11.584	10.569	9.718	8.994	8.370	7.827	7.350
	Y	73.911	66.416	60.301	55.217	50.924	47.250	44.070	41.292	38.843
	Yb	7.226	6.454	5.830	5.316	4.886	4.520	4.205	3.931	3.690
	Lu	1.163	1.038	0.937	0.854	0.784	0.725	0.675	0.630	0.592
MS63	Element	Melt Fraction								
		0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90
	Rb	114.538	104.381	95.878	88.657	82.447	77.050	72.316	68.130	64.402
	Ba	3401.388	3102.687	2852.213	2639.159	2455.722	2296.128	2156.011	2032.012	1921.500
	Th	13.139	12.000	11.042	10.226	9.523	8.910	8.371	7.893	7.467
	U	4.347	3.970	3.653	3.384	3.151	2.948	2.770	2.612	2.471
	Nb	22.068	20.183	18.594	17.238	16.065	15.043	14.142	13.343	12.630
	Ta	1.596	1.459	1.344	1.246	1.162	1.088	1.023	0.965	0.913
	La	25.879	25.861	25.842	25.824	25.805	25.787	25.768	25.750	25.732
	Ce	43.778	44.525	45.299	46.101	46.931	47.791	48.684	49.611	50.573
	Pb	14.608	13.309	12.223	11.301	10.508	9.819	9.215	8.681	8.205
	Pr	5.206	5.314	5.427	5.544	5.667	5.795	5.929	6.070	6.217
	Sr	388.902	359.377	334.019	312.004	292.711	275.665	260.495	246.908	234.668
	Nd	16.432	17.066	17.752	18.495	19.303	20.185	21.151	22.214	23.390
	Zr	304.843	279.231	257.588	239.060	223.018	208.993	196.628	185.645	175.824
	Hf	7.962	7.295	6.731	6.249	5.830	5.465	5.142	4.856	4.599
	Sm	3.064	3.218	3.389	3.578	3.790	4.029	4.299	4.609	4.967
	Eu	0.699	0.740	0.785	0.836	0.894	0.961	1.039	1.130	1.239
	Tb	0.551	0.576	0.602	0.631	0.664	0.699	0.739	0.783	0.833
	Dy	4.243	4.366	4.496	4.635	4.782	4.939	5.107	5.287	5.479
	Y	13.519	14.335	15.256	16.304	17.506	18.899	20.534	22.478	24.829
	Yb	2.709	2.733	2.757	2.781	2.806	2.831	2.857	2.883	2.910
	Lu	0.549	0.540	0.532	0.524	0.517	0.509	0.502	0.495	0.488
MS65	Element	Melt Fraction								
		0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70
	Rb	411.182	362.745	324.518	293.579	268.027	246.566	228.287	212.531	198.810
	Ba	4020.363	3927.559	3838.942	3754.237	3673.188	3595.566	3521.156	3449.763	3381.208

Th	12.068	10.387	9.117	8.123	7.325	6.670	6.122	5.658	5.259
U	4.078	3.510	3.082	2.746	2.477	2.255	2.070	1.913	1.779
Nb	21.469	19.121	17.235	15.689	14.397	13.301	12.361	11.545	10.829
Ta	1.304	1.161	1.047	0.953	0.875	0.808	0.751	0.702	0.658
La	28.900	26.431	24.352	22.575	21.040	19.701	18.522	17.476	16.542
Ce	62.253	56.781	52.193	48.292	44.933	42.010	39.445	37.175	35.152
Pb	12.473	11.407	10.510	9.743	9.080	8.502	7.993	7.542	7.139
Pr	7.669	7.018	6.468	5.999	5.592	5.238	4.926	4.648	4.401
Sr	63.272	65.865	68.680	71.747	75.100	78.782	82.844	87.347	92.369
Nd	29.652	27.352	25.384	23.679	22.189	20.876	19.709	18.666	17.728
Zr	256.820	223.402	197.680	177.269	160.678	146.928	135.345	125.455	116.912
Hf	7.149	6.219	5.503	4.934	4.472	4.090	3.767	3.492	3.254
Sm	6.473	6.051	5.680	5.353	5.061	4.799	4.563	4.349	4.155
Eu	0.630	0.640	0.651	0.662	0.673	0.685	0.698	0.710	0.724
Tb	1.222	1.144	1.076	1.015	0.960	0.911	0.867	0.827	0.791
Dy	8.320	7.749	7.251	6.814	6.426	6.080	5.769	5.489	5.234
Y	37.930	35.995	34.249	32.664	31.219	29.897	28.682	27.562	26.526
Yb	4.278	4.002	3.759	3.544	3.352	3.180	3.025	2.884	2.756
Lu	0.741	0.686	0.639	0.598	0.562	0.530	0.501	0.475	0.452

Table D2. Results of fractional partial melting calculations

[illegible]

	Hf	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Tb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Dy	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Y	0.043	0.013	0.003	0.001	0.000	0.000	0.000	0.000	0.000
	Yb	0.123	0.063	0.030	0.012	0.004	0.001	0.000	0.000	0.000
	Lu	0.015	0.007	0.003	0.001	0.000	0.000	0.000	0.000	0.000
MS3	Element	Melt Fraction								
		0.01	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40
	Rb	47.945	1.427	0.014	0.000	0.000	0.000	0.000	0.000	0.000
	Ba	402.099	262.716	150.371	83.366	44.594	22.910	11.241	5.232	2.290
	Th	4.691	0.079	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	U	2.567	0.043	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Nb	49.042	0.566	0.002	0.000	0.000	0.000	0.000	0.000	0.000
	Ta	3.117	0.036	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	La	20.851	17.952	14.753	11.988	9.620	7.611	5.925	4.528	3.386
	Ce	27.917	26.555	24.871	23.206	21.562	19.939	18.339	16.764	15.213
	Pb	4.563	2.994	1.723	0.961	0.517	0.268	0.132	0.062	0.027
	Pr	2.283	2.269	2.250	2.231	2.211	2.189	2.167	2.143	2.117
	Sr	277.435	279.097	281.290	283.627	286.128	288.814	291.714	294.860	298.297
	Nd	5.882	5.983	6.118	6.264	6.423	6.597	6.787	6.999	7.234
	Zr	214.408	175.209	134.464	101.645	75.543	55.078	39.291	27.336	18.474
	Hf	6.398	5.228	4.012	3.033	2.254	1.643	1.172	0.816	0.551
	Sm	0.894	0.921	0.956	0.996	1.039	1.087	1.141	1.202	1.272
	Eu	0.262	0.271	0.282	0.295	0.309	0.325	0.343	0.363	0.387
	Tb	0.120	0.124	0.129	0.135	0.142	0.149	0.157	0.167	0.178
	Dy	0.782	0.807	0.841	0.879	0.921	0.967	1.019	1.078	1.146
	Y	4.136	4.266	4.443	4.639	4.855	5.097	5.369	5.677	6.029
	Yb	0.491	0.505	0.524	0.545	0.568	0.594	0.623	0.655	0.692
	Lu	0.080	0.082	0.085	0.089	0.092	0.096	0.101	0.106	0.112
MS4	Element	Melt Fraction								
		0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60
	Rb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Ba	2061.647	920.343	388.607	153.925	56.611	19.084	5.800	1.554	0.357
	Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Nb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Ta	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	La	4.767	1.307	0.328	0.074	0.015	0.003	0.000	0.000	0.000
	Ce	1.982	0.311	0.043	0.005	0.001	0.000	0.000	0.000	0.000

MS9	Element	Melt Fraction								
		0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65
	Rb	185.494	198.874	214.322	232.358	253.690	279.310	310.654	349.876	400.363
	Ba	5613.883	6018.766	6486.253	7032.048	7677.586	8452.894	9401.386	10588.244	12116.008
	Th	18.076	19.380	20.885	22.644	24.723	27.220	30.276	34.099	39.021
	U	9.733	10.435	11.246	12.193	13.312	14.657	16.302	18.361	21.011
	Nb	211.290	226.515	244.093	264.614	288.883	318.028	353.680	398.288	455.703
	Ta	12.709	13.625	14.682	15.917	17.376	19.129	21.274	23.957	27.411
	La	34.274	37.340	40.939	45.218	50.378	56.708	64.635	74.816	88.311
	Ce	47.014	53.486	61.434	71.350	83.954	100.328	122.170	152.262	195.436
	Pb	22.282	23.919	25.813	28.026	30.648	33.803	37.669	42.517	48.773
	Pr	44.748	92.160	200.251	463.015	1151.620	3124.386	9417.323	32328.525	130877.607
	Sr	2128.259	2325.126	2556.920	2833.302	3167.739	3579.543	4097.347	4765.364	5655.351
	Nd	3.873	3.550	3.233	2.922	2.618	2.322	2.032	1.752	1.480
	Zr	303.107	329.642	360.738	397.627	442.020	496.354	564.222	651.136	765.971
	Hf	9.091	9.887	10.820	11.926	13.258	14.888	16.924	19.531	22.975
	Sm	0.754	0.734	0.713	0.691	0.668	0.643	0.617	0.590	0.560
	Eu	0.247	0.242	0.236	0.231	0.224	0.218	0.211	0.204	0.195
	Tb	0.105	0.103	0.101	0.099	0.097	0.095	0.092	0.089	0.086
	Dy	0.680	0.667	0.652	0.637	0.621	0.604	0.586	0.566	0.544
	Y	3.538	3.465	3.388	3.307	3.221	3.129	3.031	2.924	2.808
	Yb	0.407	0.395	0.383	0.371	0.357	0.344	0.329	0.313	0.296
	Lu	0.066	0.064	0.061	0.059	0.057	0.055	0.052	0.049	0.046
MS13	Element	Melt Fraction								
		0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90
	Rb	6400.084	7121.688	8025.104	9188.686	10743.264	12924.823	16206.514	21695.777	32728.685
	Ba	6650.175	7722.198	9126.447	11029.717	13725.546	17776.639	24395.981	36689.870	65213.101
	Th	958.676	1066.093	1200.484	1373.447	1604.331	1928.004	2414.308	3226.488	4855.442
	U	372.818	414.592	466.855	534.118	623.906	749.779	938.898	1254.745	1888.228
	Nb	1440.550	1601.960	1803.902	2063.804	2410.740	2897.107	3627.849	4848.267	7296.009
	Ta	119.200	132.557	149.267	170.773	199.480	239.725	300.192	401.177	603.719
	La	217.550	247.375	285.582	336.082	405.583	506.563	664.974	944.397	1548.388
	Ce	597.347	673.446	770.049	896.433	1068.338	1314.690	1694.786	2351.285	3730.023
	Pb	69.160	79.417	92.694	110.450	135.218	171.776	230.227	335.846	571.824
	Pr	80.696	90.858	103.740	120.567	143.414	176.087	226.371	312.944	493.965
	Sr	123.878	118.803	113.376	107.522	101.140	94.078	86.102	76.809	65.389
	Nd	371.863	417.839	475.997	551.781	654.391	800.652	1024.862	1408.959	2206.615
	Zr	10971.474	12214.468	13771.449	15777.983	18460.563	22228.014	27900.713	37400.776	56526.355
	Hf	298.114	331.888	374.194	428.715	501.605	603.973	758.110	1016.243	1535.918
	Sm	99.662	111.688	126.858	146.562	173.144	210.874	268.416	366.354	567.939
	Eu	0.174	0.141	0.111	0.084	0.061	0.042	0.027	0.015	0.007

	Tb	12.160	13.642	15.514	17.950	21.240	25.918	33.069	45.273	70.487
	Dy	54.196	61.052	69.749	81.115	96.560	118.665	152.719	211.424	334.387
	Y	173.789	198.472	230.237	272.440	330.868	416.352	551.584	792.670	1321.444
	Yb	11.922	13.955	16.641	20.317	25.580	33.592	46.888	72.074	132.111
	Lu	2.025	2.360	2.799	3.397	4.247	5.532	7.645	11.601	20.881
MS15	Element	Melt Fraction								
		0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60
	Rb	15004.318	16010.298	17160.414	18487.994	20037.496	21869.570	24069.164	26759.047	30123.472
	Ba	176114.640	188074.133	201758.586	217568.720	236039.529	257901.573	284179.202	316354.502	356654.708
	Th	1712.673	1827.463	1958.696	2110.176	2286.973	2496.006	2746.963	3053.850	3437.680
	U	555.527	592.761	635.328	684.462	741.809	809.611	891.012	990.555	1115.055
	Nb	246.491	263.576	283.152	305.802	332.305	363.728	401.568	447.996	506.280
	Ta	21.478	22.967	24.673	26.647	28.956	31.694	34.991	39.037	44.116
	La	1162.833	1242.112	1332.850	1437.712	1560.258	1705.352	1879.813	2093.513	2361.295
	Ce	1477.960	1580.111	1697.133	1832.502	1990.866	2178.580	2404.570	2681.768	3029.645
	Pb	870.612	929.127	996.037	1073.285	1163.462	1270.106	1398.171	1554.819	1750.803
	Pr	109.397	117.122	125.985	136.253	148.285	162.574	179.810	200.998	227.653
	Sr	1335.840	1431.776	1541.966	1669.790	1819.779	1998.148	2213.655	2479.036	2813.542
	Nd	309.463	331.720	357.288	386.950	421.760	463.162	513.190	574.807	652.486
	Zr	3928.059	4197.872	4506.835	4864.081	5281.813	5776.709	6372.176	7102.120	8017.548
	Hf	106.679	114.004	122.392	132.090	143.430	156.864	173.029	192.842	217.690
	Sm	31.508	33.955	36.782	40.082	43.978	48.645	54.328	61.385	70.365
	Eu	4.744	5.125	5.567	6.084	6.696	7.432	8.330	9.451	10.883
	Tb	3.520	3.806	4.138	4.527	4.989	5.543	6.222	7.070	8.155
	Dy	21.750	23.528	25.590	28.006	30.872	34.322	38.544	43.819	50.575
	Y	114.441	123.780	134.608	147.296	162.348	180.459	202.624	230.308	265.758
	Yb	11.825	12.803	13.939	15.271	16.853	18.760	21.097	24.020	27.770
	Lu	2.326	2.511	2.725	2.975	3.272	3.627	4.061	4.602	5.292
MS16	Element	Melt Fraction								
		0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80
	Rb	12964.303	14149.851	15573.244	17313.938	19491.184	22292.499	26030.642	31269.057	39135.772
	Ba	247304.665	269903.930	297035.389	330212.675	371707.399	425091.268	496320.983	596126.627	745987.469
	Th	1038.699	1133.730	1247.831	1387.373	1561.921	1786.512	2086.232	2506.274	3137.124
	U	403.939	440.895	485.268	539.534	607.414	694.755	811.312	974.662	1219.993
	Nb	418.654	457.646	504.535	561.980	633.973	726.810	851.012	1025.585	1288.698
	Ta	30.676	33.543	36.991	41.216	46.513	53.347	62.493	75.356	94.756
	La	3278.860	3579.634	3940.847	4382.715	4935.584	5647.191	6597.188	7929.130	9930.577
	Ce	6654.747	7265.002	7997.866	8894.341	10015.981	11459.608	13386.766	16088.599	20148.262
	Pb	1654.243	1805.688	1987.535	2209.943	2488.163	2846.178	3323.997	3993.707	4999.656
	Pr	839.849	916.861	1009.345	1122.476	1264.020	1446.196	1689.389	2030.336	2542.624
	Sr	181912.013	198541.027	218505.503	242919.533	273455.163	312741.489	365163.352	438619.752	548923.639

	Nd	3338.033	3644.153	4011.778	4461.477	5024.130	5748.306	6715.045	8070.403	10106.928
	Zr	8827.856	9646.523	10630.650	11835.800	13345.481	15291.211	17892.731	21546.722	27049.275
	Hf	249.694	272.831	300.643	334.698	377.355	432.327	505.819	609.029	764.429
	Sm	635.969	694.352	764.473	850.257	957.600	1095.775	1280.260	1538.950	1927.731
	Eu	159.940	174.652	192.325	213.950	241.016	275.864	322.405	387.686	485.836
	Tb	62.652	68.425	75.361	83.849	94.475	108.160	126.440	152.089	190.664
	Dy	238.795	260.971	287.632	320.285	361.196	413.932	484.455	583.532	732.774
	Y	676.181	740.170	817.233	911.792	1030.509	1183.901	1389.583	1679.452	2117.744
	Yb	39.178	42.984	47.579	53.233	60.351	69.580	82.002	99.587	126.320
	Lu	6.848	7.511	8.310	9.293	10.531	12.134	14.291	17.342	21.976
MS17	Element	Melt Fraction								
		0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75
	Rb	99.442	107.908	117.930	129.980	144.737	163.227	187.062	218.937	263.718
	Ba	192.165	221.415	258.284	305.751	368.438	453.849	574.864	755.213	1042.871
	Th	13.646	14.801	16.168	17.810	19.820	22.337	25.579	29.912	35.992
	U	7.348	7.970	8.706	9.590	10.672	12.028	13.773	16.106	19.380
	Nb	97.893	106.233	116.108	127.982	142.525	160.749	184.242	215.664	259.816
	Ta	5.427	5.890	6.439	7.098	7.906	8.919	10.225	11.973	14.429
	La	22.244	25.970	30.731	36.955	45.311	56.909	73.687	99.294	141.296
	Ce	60.671	70.962	84.138	101.394	124.617	156.928	203.804	275.583	393.767
	Pb	2.496	2.823	3.227	3.736	4.393	5.266	6.466	8.195	10.848
	Pr	9.442	11.056	13.124	15.835	19.490	24.581	31.981	43.333	62.068
	Sr	56.118	55.062	53.936	52.729	51.427	50.009	48.448	46.707	44.729
	Nd	49.804	61.377	77.027	98.785	130.057	176.871	250.629	374.785	603.211
	Zr	2641.038	2866.366	3133.172	3454.009	3847.045	4339.597	4974.706	5824.317	7018.379
	Hf	79.152	85.905	93.901	103.517	115.297	130.059	149.094	174.558	210.345
	Sm	18.749	24.738	33.437	46.512	66.991	100.729	159.948	272.780	512.877
	Eu	0.315	0.302	0.289	0.275	0.260	0.245	0.228	0.210	0.191
	Tb	2.704	3.310	4.124	5.248	6.849	9.224	12.927	19.087	30.261
	Dy	15.960	18.439	21.573	25.620	30.983	38.318	48.755	64.385	89.459
	Y	688.747	1343.992	2779.782	6162.072	14855.873	39730.997	121194.902	439168.353	2013544.341
	Yb	8.894	10.033	11.436	13.199	15.466	18.465	22.574	28.466	37.450
	Lu	1.798	1.996	2.236	2.533	2.906	3.390	4.036	4.936	6.262
MS18	Element	Melt Fraction								
		0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45
	Rb	3505.393	3704.170	3926.581	4177.091	4461.361	4786.679	5162.587	5601.830	6121.809
	Ba	6661.799	7297.026	8034.554	8898.430	9920.381	11142.997	12624.605	14446.921	16727.495
	Th	479.693	506.773	537.067	571.179	609.877	654.150	705.292	765.030	835.722
	U	155.594	164.378	174.204	185.269	197.821	212.182	228.770	248.147	271.077
	Nb	233.397	246.814	261.837	278.772	298.006	320.037	345.518	375.325	410.650
	Ta	20.338	21.507	22.816	24.291	25.967	27.887	30.107	32.705	35.783

	La	40.562	45.726	51.903	59.368	68.498	79.817	94.066	112.328	136.222
	Ce	75.765	86.881	100.412	117.072	137.856	164.171	198.058	242.558	302.345
	Pb	18.370	19.891	21.637	23.656	26.013	28.793	32.111	36.126	41.062
	Pr	8.521	9.866	11.520	13.578	16.175	19.502	23.842	29.621	37.502
	Sr	15.002	14.790	14.569	14.338	14.097	13.843	13.576	13.293	12.992
	Nd	27.975	37.982	52.477	73.939	106.511	157.346	239.265	376.253	615.458
	Zr	3126.226	3305.430	3506.063	3732.187	3988.957	4283.017	4623.069	5020.745	5491.943
	Hf	82.790	87.538	92.854	98.845	105.649	113.441	122.451	132.989	145.476
	Sm	0.118	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Eu	0.189	0.184	0.179	0.174	0.169	0.164	0.158	0.152	0.146
	Tb	0.865	1.471	2.576	4.668	8.789	17.289	35.758	78.388	183.993
	Dy	5.128	6.060	7.231	8.721	10.646	13.175	16.566	21.214	27.759
	Y	10.072	8.019	6.301	4.880	3.717	2.779	2.033	1.450	1.005
	Yb	4.012	4.437	4.936	5.527	6.233	7.089	8.139	9.448	11.112
	Lu	0.971	1.050	1.141	1.246	1.368	1.512	1.684	1.891	2.145
MS19	Element	Melt Fraction								
		0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50
	Rb	2242.248	2377.157	2529.129	2701.604	2899.010	3127.148	3393.765	3709.444	4089.026
	Ba	1818.194	2037.447	2298.957	2614.335	2999.473	3476.591	4077.521	4849.168	5862.964
	Th	291.480	308.884	328.481	350.711	376.141	405.515	439.823	480.419	529.199
	U	113.353	120.122	127.742	136.387	146.277	157.700	171.042	186.829	205.799
	Nb	502.927	532.898	566.642	604.914	648.692	699.250	758.293	828.145	912.065
	Ta	40.673	43.098	45.827	48.924	52.465	56.556	61.333	66.984	73.774
	La	41.466	46.494	52.496	59.738	68.588	79.561	93.392	111.167	134.544
	Ce	83.111	92.896	104.535	118.533	135.577	156.623	183.039	216.834	261.052
	Pb	19.814	21.790	24.102	26.832	30.094	34.042	38.889	44.943	52.663
	Pr	10.443	11.670	13.128	14.882	17.017	19.653	22.960	27.189	32.720
	Sr	94.073	92.998	91.871	90.687	89.437	88.115	86.708	85.204	83.587
	Nd	36.278	41.751	48.461	56.793	67.291	80.738	98.295	121.739	153.882
	Zr	8022.375	8501.042	9039.985	9651.319	10350.637	11158.347	12101.688	13217.845	14558.936
	Hf	212.355	225.030	239.302	255.491	274.010	295.401	320.384	349.945	385.464
	Sm	7.278	8.646	10.379	12.606	15.519	19.402	24.693	32.094	42.769
	Eu	0.322	0.314	0.305	0.296	0.287	0.277	0.267	0.257	0.246
	Tb	1.088	1.239	1.423	1.648	1.928	2.282	2.739	3.338	4.147
	Dy	8.467	9.318	10.314	11.491	12.899	14.604	16.699	19.319	22.663
	Y	30.974	40.078	52.675	70.463	96.170	134.317	192.683	285.232	438.330
	Yb	6.579	7.096	7.689	8.375	9.176	10.122	11.253	12.627	14.326
	Lu	1.658	1.774	1.907	2.058	2.234	2.439	2.682	2.974	3.330
MS22	Element	Melt Fraction								
		0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70
	Rb	157.565	169.837	184.166	201.118	221.482	246.402	277.594	317.758	371.403

248	MS23	Ba	808.090	875.182	953.918	1047.565	1160.726	1300.098	1475.805	1703.895	2011.380
		Th	16.891	18.205	19.740	21.555	23.736	26.404	29.744	34.044	39.786
		U	9.095	9.803	10.629	11.607	12.781	14.218	16.016	18.331	21.423
		Nb	71.593	77.257	83.880	91.725	101.163	112.730	127.233	145.945	170.993
		Ta	3.881	4.189	4.550	4.976	5.490	6.120	6.910	7.929	9.295
		La	34.534	37.943	42.003	46.912	52.949	60.532	70.300	83.295	101.311
		Ce	53.829	61.720	71.547	84.013	100.173	121.678	151.228	193.499	257.190
		Pb	8.597	9.315	10.159	11.164	12.378	13.875	15.763	18.217	21.529
		Pr	50.952	97.458	196.352	420.472	968.235	2434.571	6824.614	21957.764	84618.528
		Sr	3.409E+06	2.316E+07	1.835E+08	1.740E+09	2.046E+10	3.118E+11	6.553E+12	2.069E+14	1.114E+16
		Nd	3.543	3.206	2.879	2.560	2.252	1.954	1.667	1.393	1.132
		Zr	317.745	348.002	383.928	427.201	480.218	546.515	631.521	743.992	898.959
		Hf	9.567	10.477	11.558	12.859	14.453	16.447	19.002	22.383	27.041
		Sm	0.750	0.728	0.705	0.680	0.654	0.627	0.598	0.566	0.532
		Eu	0.233	0.228	0.223	0.218	0.212	0.205	0.198	0.191	0.182
		Tb	0.105	0.103	0.101	0.099	0.096	0.094	0.091	0.088	0.084
		Dy	0.681	0.666	0.650	0.633	0.615	0.596	0.575	0.552	0.527
		Y	3.578	3.494	3.406	3.313	3.214	3.108	2.994	2.869	2.732
		Yb	0.407	0.394	0.380	0.366	0.351	0.335	0.318	0.300	0.280
		Lu	0.065	0.063	0.061	0.058	0.056	0.053	0.050	0.047	0.044
248	MS23	Element	Melt Fraction								
			0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50
		Rb	447.826	543.602	667.662	830.990	1050.013	1349.976	1770.911	2378.645	3286.118
		Ba	888.840	871.248	852.970	833.932	814.050	793.222	771.324	748.205	723.675
		Th	20.676	21.915	23.310	24.893	26.705	28.797	31.242	34.136	37.615
		U	13.157	13.946	14.834	15.841	16.994	18.326	19.882	21.723	23.937
		Nb	20.196	29.423	43.854	67.070	105.630	172.055	291.417	516.757	967.799
		Ta	0.807	1.206	1.847	2.907	4.722	7.950	13.956	25.728	50.280
		La	13.593	15.122	16.932	19.098	21.721	24.940	28.956	34.058	40.683
		Ce	28.323	32.422	37.418	43.587	51.309	61.135	73.872	90.745	113.681
		Pb	28.118	30.249	32.686	35.497	38.770	42.622	47.214	52.769	59.606
		Pr	4.307	4.972	5.791	6.811	8.101	9.759	11.935	14.853	18.874
		Sr	84.850	81.106	77.315	73.474	69.579	65.624	61.606	57.515	53.346
		Nd	22.398	31.332	44.731	65.344	97.985	151.413	242.272	403.844	706.790
		Zr	1164.098	1238.227	1322.016	1417.455	1527.113	1654.368	1803.753	1981.484	2196.326
		Hf	34.478	36.670	39.147	41.968	45.208	48.969	53.382	58.632	64.977
		Sm	0.086	0.012	0.002	0.000	0.000	0.000	0.000	0.000	0.000
		Eu	0.450	0.427	0.403	0.380	0.356	0.332	0.309	0.285	0.261
		Tb	2.139	3.451	5.732	9.837	17.522	32.577	63.651	131.832	292.683
		Dy	10.959	12.839	15.186	18.158	21.982	26.990	33.689	42.869	55.820
		Y	15.181	12.729	10.559	8.655	6.997	5.568	4.351	3.327	2.481

	Yb	7.091	7.875	8.802	9.909	11.247	12.885	14.924	17.509	20.856
	Lu	1.619	1.757	1.916	2.102	2.320	2.580	2.893	3.277	3.756
MS26	Element	Melt Fraction								
		0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90
	Rb	4979.662	5544.354	6251.761	7163.525	8382.643	10095.050	12673.921	16993.765	25693.286
	Ba	175053.453	194708.362	219304.413	250967.676	293246.186	352535.983	441651.940	590561.516	889432.333
	Th	380.489	424.019	478.603	549.032	643.318	775.947	976.036	1311.945	1990.470
	U	135.782	151.317	170.796	195.929	229.576	276.907	348.311	468.184	710.324
	Nb	112.774	129.374	150.840	179.515	219.460	278.327	372.273	541.625	918.767
	Ta	7.128	8.235	9.678	11.621	14.353	18.427	25.017	37.104	64.670
	La	191.752	228.589	278.208	347.608	449.516	609.265	883.966	1428.275	2808.678
	Ce	824.292	1205.147	1842.673	2982.039	5198.298	10030.326	22422.415	63255.048	272845.246
	Pb	375.898	419.687	474.703	545.849	641.340	776.066	980.056	1324.087	2023.390
	Pr	0.038	0.018	0.008	0.003	0.001	0.000	0.000	0.000	0.000
	Sr	5264.110	6017.751	6988.674	8280.204	10070.693	12694.474	16853.283	24285.613	40641.920
	Nd	6.541	5.932	5.319	4.700	4.074	3.441	2.798	2.143	1.472
	Zr	1434.574	1672.731	1986.068	2412.860	3020.816	3940.499	5455.347	8297.602	14984.792
	Hf	38.304	44.575	52.808	63.996	79.890	103.857	143.183	216.611	388.222
	Sm	1.226	1.181	1.133	1.080	1.023	0.958	0.885	0.799	0.692
	Eu	0.319	0.310	0.300	0.289	0.277	0.263	0.247	0.228	0.203
	Tb	0.163	0.159	0.154	0.149	0.143	0.137	0.129	0.120	0.108
	Dy	1.089	1.055	1.019	0.980	0.936	0.887	0.831	0.763	0.677
	Y	5.595	5.434	5.258	5.066	4.853	4.613	4.335	4.001	3.574
	Yb	0.637	0.608	0.577	0.544	0.508	0.468	0.424	0.374	0.312
	Lu	0.106	0.100	0.095	0.089	0.082	0.075	0.067	0.058	0.048
MS27	Element	Melt Fraction								
		0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75
	Rb	20556.190	22279.023	24316.037	26761.682	29752.459	33493.232	38306.136	44728.444	53728.046
	Ba	530750.389	575219.815	627797.532	690920.857	768112.063	864657.385	988868.725	1154608.639	1386849.287
	Th	1940.544	2103.293	2295.733	2526.789	2809.367	3162.833	3617.642	4224.594	5075.212
	U	599.415	649.687	709.130	780.501	867.786	976.969	1117.455	1304.936	1567.684
	Nb	2798.632	3033.695	3311.674	3645.480	4053.776	4564.581	5221.958	6099.423	7329.452
	Ta	184.889	200.425	218.797	240.861	267.848	301.613	345.069	403.077	484.398
	La	932.677	1014.901	1112.526	1230.272	1374.988	1557.010	1792.682	2109.439	2557.081
	Ce	1471.505	1604.019	1761.641	1952.127	2186.757	2482.590	2866.667	3384.513	4119.028
	Pb	2009.600	2178.264	2377.708	2617.190	2910.093	3276.503	3748.009	4377.307	5259.348
	Pr	171.171	186.690	205.160	227.494	255.025	289.763	334.903	395.826	482.342
	Sr	37399.411	40542.354	44259.263	48722.859	54182.816	61013.957	69805.837	81542.083	97995.379
	Nd	495.104	541.716	597.378	664.933	748.537	854.501	992.888	1180.740	1449.307
	Zr	18183.535	19724.724	21548.630	23740.600	26424.096	29784.627	34114.253	39900.780	48024.421
	Hf	482.176	523.043	571.408	629.533	700.692	789.803	904.613	1058.055	1273.471

	Sm	85.051	93.403	103.416	115.618	130.791	150.120	175.512	210.209	260.206
	Eu	19.471	21.461	23.855	26.785	30.444	35.130	41.321	49.836	62.200
	Tb	13.457	14.775	16.356	18.282	20.676	23.725	27.729	33.199	41.078
	Dy	83.571	91.753	101.558	113.505	128.354	147.264	172.095	206.009	254.849
	Y	227.641	255.492	289.646	332.318	386.843	458.454	555.800	694.151	902.882
	Yb	23.033	25.801	29.188	33.412	38.794	45.845	55.400	68.933	89.266
	Lu	4.099	4.565	5.132	5.835	6.724	7.879	9.430	11.605	14.832
MS28	Element	Melt Fraction								
		0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80
	Rb	14555.387	15903.091	17522.952	19506.308	21990.418	25191.407	29470.317	35478.749	44524.036
	Ba	19759.477	22117.077	25023.548	28682.985	33410.937	39720.337	48499.531	61420.167	82006.966
	Th	403.019	440.364	485.253	540.219	609.068	697.795	816.414	982.998	1233.817
	U	124.434	135.965	149.825	166.796	188.053	215.448	252.072	303.506	380.948
	Nb	251.254	276.779	307.723	345.972	394.385	457.514	543.059	665.109	852.419
	Ta	12.279	13.549	15.092	17.002	19.426	22.594	26.899	33.061	42.556
	La	140.984	162.588	190.069	225.885	273.971	340.978	438.957	591.786	853.015
	Ce	295.019	346.139	412.355	500.389	621.230	793.886	1053.683	1472.757	2218.770
	Pb	85.944	95.734	107.742	122.778	142.082	167.664	202.976	254.458	335.559
	Pr	38.831	46.176	55.826	68.856	87.054	113.568	154.367	221.928	346.074
	Sr	71.879	68.329	64.641	60.795	56.766	52.520	48.012	43.177	37.917
	Nd	233.568	311.495	426.987	605.091	893.468	1389.849	2314.658	4231.444	8854.272
	Zr	3440.540	3787.238	4207.222	4725.898	5381.783	6236.123	7392.374	9039.673	11563.346
	Hf	95.985	105.619	117.286	131.688	149.892	173.592	205.648	251.286	321.146
	Sm	4.344E+04	1.884E+05	9.402E+05	5.558E+06	4.052E+07	3.852E+08	5.185E+09	1.122E+11	4.836E+12
	Eu	0.671	0.624	0.576	0.528	0.478	0.428	0.376	0.323	0.268
	Tb	1.904E+04	9.631E+04	5.687E+05	4.050E+06	3.635E+07	4.375E+08	7.732E+09	2.310E+11	1.476E+13
	Dy	116.022	174.294	272.194	445.544	772.920	1443.337	2968.131	6963.379	19773.150
	Y	5.367	3.914	2.770	1.890	1.233	0.760	0.434	0.224	0.100
	Yb	43.072	61.052	89.466	136.494	218.877	373.859	693.613	1440.718	3524.686
	Lu	4.103	5.167	6.651	8.793	12.013	17.112	25.744	41.732	75.373
MS29	Element	Melt Fraction								
		0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80
	Rb	2139.099	2344.187	2591.467	2895.288	3277.288	3771.671	4435.835	5373.907	6796.089
	Ba	5102.953	6000.088	7164.768	8717.077	10853.790	13916.250	18540.897	26032.227	39435.795
	Th	589.845	644.453	710.088	790.451	891.102	1020.798	1194.166	1437.604	1804.075
	U	191.590	209.328	230.647	256.750	289.443	331.570	387.882	466.955	585.990
	Nb	261.070	287.156	318.732	357.693	406.911	470.951	557.511	680.648	868.954
	Ta	16.373	18.022	20.019	22.486	25.606	29.669	35.167	43.000	55.000
	La	164.559	194.936	234.682	288.115	362.372	469.959	634.453	904.811	1397.117
	Ce	395.185	499.746	646.282	858.757	1179.976	1691.721	2564.147	4193.382	7656.246
	Pb	73.804	82.940	94.250	108.557	127.136	152.073	187.003	238.811	322.136

	Pr	152.171	242.303	403.326	708.414	1329.727	2715.206	6190.391	16407.487	54093.958	152.171
	Sr	100.649	97.399	93.958	90.296	86.371	82.127	77.487	72.336	66.495	100.649
	Nd	4.727	3.545	2.586	1.825	1.236	0.795	0.477	0.261	0.125	4.727
	Zr	3201.658	3529.588	3927.463	4419.690	5043.333	5857.446	6962.007	8540.271	10966.730	3201.658
	Hf	86.107	94.913	105.597	118.812	135.552	157.401	187.038	229.374	294.441	86.107
	Sm	2.265	2.095	1.923	1.750	1.574	1.396	1.216	1.032	0.845	2.265
	Eu	0.487	0.472	0.457	0.441	0.424	0.405	0.384	0.361	0.335	0.487
	Tb	0.333	0.314	0.295	0.276	0.255	0.234	0.211	0.188	0.162	0.333
	Dy	2.137	1.985	1.830	1.673	1.514	1.351	1.185	1.015	0.840	2.137
	Y	10.533	9.953	9.354	8.734	8.089	7.416	6.708	5.957	5.151	10.533
	Yb	0.924	0.795	0.673	0.561	0.457	0.362	0.277	0.202	0.137	0.924
	Lu	0.114	0.092	0.073	0.056	0.042	0.030	0.021	0.013	0.008	0.114
MS30	Element	Melt Fraction									
		0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	
	Rb	11600.773	12767.341	14193.910	15978.186	18273.796	21336.969	25629.279	32074.759	42832.030	
	Ba	447703.918	492724.779	547779.786	616639.604	705233.181	823448.943	989100.316	1237848.091	1652999.088	
	Th	1244.290	1369.416	1522.428	1713.808	1960.034	2288.587	2748.977	3440.315	4594.132	
	U	409.035	450.167	500.467	563.379	644.321	752.326	903.669	1130.932	1510.226	
	Nb	1460.470	1607.325	1786.909	2011.521	2300.501	2686.100	3226.420	4037.773	5391.870	
	Ta	123.445	135.857	151.036	170.021	194.447	227.039	272.709	341.288	455.741	
	La	1038.252	1144.342	1274.279	1437.078	1646.940	1927.597	2321.900	2915.869	3911.144	
	Ce	1167.847	1289.578	1438.964	1626.540	1868.938	2194.021	2652.249	3345.272	4512.398	
	Pb	618.964	681.468	757.932	853.613	976.776	1141.215	1371.794	1718.323	2297.266	
	Pr	79.556	88.169	98.780	112.160	129.534	152.964	186.204	236.870	323.043	
	Sr	12152.117	13396.105	14919.988	16829.652	19291.925	22585.665	27214.520	34189.857	45883.338	
	Nd	179.021	199.939	225.918	258.976	302.342	361.511	446.610	578.484	807.519	
	Zr	3685.977	4068.201	4537.019	5125.352	5885.143	6903.358	8337.367	10503.891	14147.734	
	Hf	102.661	113.307	126.364	142.751	163.912	192.271	232.211	292.553	394.041	
	Sm	24.461	27.891	32.246	37.924	45.579	56.357	72.440	98.497	146.374	
	Eu	5.927	6.843	8.020	9.578	11.713	14.776	19.449	27.224	41.999	
	Tb	3.725	4.366	5.204	6.332	7.910	10.226	13.856	20.096	32.455	
	Dy	24.421	28.871	34.739	42.721	54.011	70.802	97.520	144.304	239.157	
	Y	139.554	174.034	222.144	291.834	397.631	568.289	866.963	1453.792	2830.973	
	Yb	23.907	33.270	47.944	72.130	114.609	195.601	368.089	798.016	2164.053	
	Lu	3.139	4.172	5.716	8.127	12.110	19.193	33.091	64.450	152.220	
MS33	Element	Melt Fraction									
		0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	
	Rb	109.982	119.362	130.468	143.822	160.181	180.680	207.112	242.468	292.155	
	Ba	497.629	557.922	631.781	723.950	841.564	995.805	1205.129	1502.061	1949.046	
	Th	16.228	17.601	19.226	21.178	23.569	26.561	30.416	35.566	42.795	
	U	8.431	9.144	9.988	11.003	12.244	13.799	15.801	18.477	22.233	

		0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85
	Rb	5628.941	6199.787	6898.432	7773.054	8899.478	10404.299	12515.848	15691.890	21003.728
	Ba	6146.442	6916.835	7881.317	9119.571	10760.283	13024.698	16325.614	21524.671	30741.835
	Th	811.986	894.005	994.349	1119.913	1281.548	1497.363	1799.995	2254.838	3014.797
	U	243.247	267.818	297.878	335.493	383.915	448.566	539.226	675.484	903.146
	Nb	2175.160	2394.750	2663.383	2999.517	3432.184	4009.831	4819.780	6036.962	8070.364
	Ta	137.423	151.296	168.268	189.504	216.839	253.334	304.505	381.405	509.872
	La	230.118	260.033	297.647	346.174	410.824	500.611	632.460	841.975	1217.603
	Ce	380.883	440.368	516.993	618.540	757.992	958.509	1265.189	1777.083	2753.823
	Pb	78.444	87.947	99.797	114.945	134.918	162.327	202.019	264.036	372.874
	Pr	52.321	66.546	86.811	116.853	163.667	241.479	382.530	671.715	1388.115
	Sr	87.317	81.487	75.494	69.314	62.918	56.265	49.298	41.934	34.039
	Nd	0.248	0.118	0.052	0.021	0.007	0.002	0.001	0.000	0.000
	Zr	2838.767	3160.968	3559.866	4065.677	4726.577	5624.211	6908.387	8885.656	12291.877
	Hf	76.115	84.754	95.449	109.011	126.731	150.799	185.231	238.247	329.576
	Sm	2.019	1.862	1.703	1.542	1.377	1.208	1.035	0.857	0.672
	Eu	0.521	0.502	0.481	0.459	0.435	0.410	0.381	0.348	0.311
	Tb	0.300	0.286	0.271	0.256	0.239	0.221	0.202	0.180	0.156
	Dy	1.919	1.815	1.707	1.594	1.475	1.348	1.212	1.065	0.900
	Y	10.026	9.457	8.865	8.247	7.599	6.913	6.182	5.391	4.519
	Yb	1.001	0.920	0.838	0.754	0.670	0.584	0.496	0.407	0.315
	Lu	0.157	0.143	0.129	0.115	0.100	0.086	0.072	0.058	0.043
MS37	Element	Melt Fraction								
		0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70
	Rb	2.170	0.843	0.304	0.100	0.030	0.008	0.002	0.000	0.000
	Ba	572.475	563.648	554.266	544.245	533.476	521.819	509.088	495.031	479.285
	Th	15.657	16.901	18.356	20.079	22.153	24.696	27.886	32.004	37.519
	U	9.964	10.755	11.681	12.778	14.098	15.716	17.746	20.366	23.876
	Nb	2.072	1.632	1.261	0.953	0.701	0.500	0.342	0.222	0.135
	Ta	0.084	0.067	0.052	0.040	0.030	0.022	0.015	0.010	0.006
	La	854.669	2431.633	7522.520	25676.127	98525.127	435660.692	2295457.793	15103897.279	132939597.581
	Ce	2.632	1.992	1.474	1.063	0.743	0.500	0.321	0.194	0.109
	Pb	40.307	44.262	48.971	54.660	61.652	70.427	81.724	96.738	117.531
	Pr	0.518	0.416	0.329	0.254	0.192	0.141	0.099	0.067	0.042
	Sr	72.066	63.682	55.719	48.188	41.102	34.474	28.322	22.665	17.524
	Nd	3.542	3.264	2.989	2.716	2.446	2.178	1.913	1.652	1.394
	Zr	1000.806	1088.234	1191.262	1314.355	1463.831	1648.930	1883.693	2190.522	2607.384
	Hf	29.555	32.130	35.163	38.786	43.185	48.630	55.535	64.555	76.804
	Sm	1.032	0.980	0.926	0.871	0.814	0.756	0.696	0.633	0.568
	Eu	0.259	0.251	0.243	0.235	0.226	0.216	0.206	0.195	0.183
	Tb	0.258	0.243	0.229	0.214	0.199	0.184	0.168	0.151	0.134

	Dy	1.599	1.347	1.119	0.915	0.733	0.575	0.437	0.321	0.225
	Y	7.737	7.457	7.166	6.863	6.545	6.211	5.858	5.482	5.077
	Yb	17.503	24.601	35.535	52.997	82.112	133.234	228.880	422.687	858.160
	Lu	1.841	2.093	2.405	2.797	3.300	3.962	4.861	6.128	8.007
MS38	Element	Melt Fraction								
		0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70
	Rb	3146.245	3393.389	3682.177	4024.055	4435.073	4938.459	5569.129	6382.075	7469.200
	Ba	3532.162	3968.773	4501.170	5161.242	5995.853	7076.397	8516.438	10506.544	13388.895
	Th	304.087	327.920	355.765	388.722	428.337	476.843	537.600	615.895	720.563
	U	118.256	127.525	138.353	151.170	166.575	185.439	209.067	239.515	280.219
	Nb	283.522	306.006	332.298	363.448	400.929	446.877	504.504	578.874	678.461
	Ta	21.219	22.908	24.882	27.223	30.039	33.494	37.827	43.423	50.919
	La	68.171	81.871	99.778	123.713	156.569	203.133	271.761	378.004	553.266
	Ce	153.838	196.683	256.459	342.217	469.390	665.637	983.622	1531.419	2552.988
	Pb	37.197	41.325	46.299	52.388	59.980	69.660	82.342	99.534	123.890
	Pr	23.883	32.475	45.257	64.919	96.383	149.186	243.124	422.947	801.447
	Sr	118.217	115.643	112.927	110.047	106.976	103.681	100.117	96.225	91.919
	Nd	0.058	0.018	0.005	0.001	0.000	0.000	0.000	0.000	0.000
	Zr	3134.421	3387.587	3684.046	4035.818	4459.803	4980.519	5634.924	6481.418	7617.942
	Hf	85.168	92.047	100.102	109.660	121.181	135.329	153.111	176.111	206.993
	Sm	1.060	0.887	0.732	0.594	0.472	0.366	0.276	0.200	0.138
	Eu	0.271	0.262	0.254	0.245	0.235	0.225	0.215	0.203	0.190
	Tb	0.136	0.112	0.090	0.072	0.056	0.042	0.031	0.022	0.014
	Dy	0.039	0.016	0.006	0.002	0.001	0.000	0.000	0.000	0.000
	Y	5.329	4.840	4.362	3.895	3.441	3.001	2.575	2.165	1.772
	Yb	10.066	14.461	21.387	32.727	52.153	87.295	155.268	298.271	633.754
	Lu	0.945	1.146	1.412	1.771	2.269	2.985	4.056	5.743	8.578
MS39	Element	Melt Fraction								
		0.70	0.75	0.80	0.85	0.90	0.95			
	Rb	12952.485	15575.705	19519.810	26112.924	39353.013	79337.841			
	Ba	252028.502	302981.802	379566.698	507535.571	764372.281	1539294.641			
	Th	1027.028	1235.271	1548.441	2072.093	3124.076	6303.018			
	U	399.400	480.383	602.171	805.814	1214.918	2451.174			
	Nb	397.586	481.780	609.459	825.217	1264.974	2625.542			
	Ta	29.179	35.409	44.872	60.894	93.642	195.421			
	La	377.736	474.518	627.330	899.097	1493.186	3554.118			
	Ce	711.308	1016.612	1573.906	2765.058	6118.223	23783.275			
	Pb	708.982	855.998	1078.037	1451.320	2206.793	4517.410			
	Pr	3.829E+18	2.004E+21	4.262E+24	8.311E+28	9.250E+34	2.008E+45			
	Sr	11622.070	14780.402	19836.493	28986.796	49474.522	123395.217			
	Nd	2.369	1.949	1.535	1.129	0.732	0.349			

	Zr	2100.887	2654.938	3535.622	5115.171	8608.417	20959.490			
	Hf	57.342	72.426	96.389	139.335	234.216	569.121			
	Sm	0.602	0.565	0.522	0.472	0.410	0.322			
	Eu	0.166	0.158	0.148	0.137	0.123	0.101			
	Tb	0.068	0.066	0.062	0.058	0.053	0.045			
	Dy	0.433	0.412	0.389	0.361	0.325	0.271			
	Y	2.322	2.209	2.077	1.919	1.717	1.419			
	Yb	0.243	0.227	0.209	0.187	0.161	0.124			
	Lu	0.041	0.038	0.035	0.031	0.026	0.020			
MS40	Element	Melt Fraction								
		0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45
	Rb	105.751	111.705	118.365	125.863	134.368	144.096	155.331	168.452	183.975
	Ba	319.704	340.188	363.272	389.469	419.438	454.030	494.370	541.977	598.943
	Th	11.933	12.604	13.354	14.199	15.157	16.252	17.518	18.995	20.743
	U	6.425	6.787	7.191	7.645	8.161	8.751	9.433	10.228	11.169
	Nb	126.939	134.072	142.049	151.029	161.214	172.862	186.313	202.020	220.599
	Ta	7.635	8.064	8.544	9.084	9.697	10.398	11.207	12.152	13.269
	La	16.961	18.315	19.865	21.651	23.731	26.175	29.081	32.583	36.871
	Ce	27.010	30.281	34.170	38.841	44.519	51.508	60.244	71.350	85.757
	Pb	3.990	4.243	4.527	4.850	5.219	5.644	6.140	6.724	7.423
	Pr	3.719	6.448	11.535	21.377	41.226	83.191	176.845	399.335	968.006
	Sr	181.972	167.323	153.117	139.365	126.080	113.276	100.967	89.170	77.905
	Nd	5.484	5.070	4.667	4.274	3.892	3.521	3.162	2.816	2.482
	Zr	263.631	281.011	300.633	322.944	348.517	378.099	412.677	453.585	502.667
	Hf	7.902	8.423	9.011	9.680	10.446	11.333	12.370	13.596	15.068
	Sm	0.912	0.890	0.868	0.844	0.820	0.795	0.768	0.741	0.713
	Eu	0.256	0.252	0.248	0.243	0.239	0.234	0.229	0.224	0.218
	Tb	0.126	0.124	0.122	0.120	0.117	0.115	0.112	0.110	0.107
	Dy	0.831	0.816	0.799	0.783	0.765	0.747	0.728	0.708	0.687
	Y	4.232	4.153	4.071	3.985	3.896	3.803	3.705	3.603	3.494
	Yb	0.522	0.507	0.492	0.477	0.461	0.445	0.428	0.410	0.392
	Lu	0.085	0.083	0.080	0.077	0.074	0.072	0.069	0.065	0.062
MS41	Element	Melt Fraction								
		0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	
	Rb	105.872	111.833	118.501	126.007	134.521	144.260	155.508	168.644	
	Ba	336.856	358.270	382.391	409.751	441.033	477.119	519.176	568.776	
	Th	9.039	9.549	10.119	10.762	11.491	12.325	13.288	14.413	
	U	4.867	5.142	5.449	5.795	6.187	6.636	7.155	7.761	
	Nb	51.397	54.335	57.623	61.329	65.536	70.353	75.922	82.434	
	Ta	2.713	2.868	3.043	3.239	3.462	3.718	4.013	4.359	

	La	12.333	13.523	14.907	16.530	18.452	20.754	23.548	26.990	
	Ce	21.715	25.946	31.318	38.237	47.290	59.350	75.752	98.593	
	Pb	4.098	4.357	4.648	4.978	5.355	5.790	6.297	6.894	
	Pr	1.003	0.531	0.271	0.133	0.062	0.028	0.012	0.005	
	Sr	188.760	171.631	155.209	139.505	124.530	110.294	96.810	84.092	
	Nd	4.827	4.562	4.299	4.036	3.773	3.512	3.251	2.991	
	Zr	241.568	257.773	276.089	296.939	320.869	348.587	381.032	419.477	
	Hf	7.262	7.749	8.299	8.926	9.645	10.477	11.452	12.607	
	Sm	0.824	0.807	0.789	0.770	0.751	0.731	0.711	0.689	
	Eu	0.235	0.232	0.228	0.225	0.221	0.217	0.213	0.209	
	Tb	0.118	0.116	0.114	0.112	0.110	0.108	0.106	0.104	
	Dy	0.786	0.772	0.758	0.743	0.728	0.712	0.695	0.677	
	Y	3.804	3.742	3.678	3.611	3.541	3.467	3.390	3.309	
	Yb	0.500	0.487	0.474	0.460	0.446	0.431	0.415	0.399	
	Lu	0.083	0.081	0.078	0.076	0.073	0.070	0.067	0.064	
MS43	Element	Melt Fraction								
		0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75
MS43	Rb	26271.567	28479.175	31089.920	34225.113	38060.112	42858.168	49033.346	57276.471	68832.531
	Ba	43200.571	47146.036	51844.820	57530.851	64544.913	73403.017	84924.611	100491.828	122627.071
	Th	597.745	648.014	707.465	778.864	866.207	975.493	1116.160	1303.953	1567.255
	U	210.761	228.485	249.447	274.622	305.418	343.952	393.550	459.764	552.603
	Nb	100.979	111.685	124.614	140.500	160.429	186.072	220.135	267.282	336.244
	Ta	5.645	6.243	6.966	7.854	8.968	10.402	12.306	14.941	18.796
	La	101.045	114.366	130.846	151.636	178.482	214.159	263.304	334.221	443.138
	Ce	187.131	226.639	279.106	350.613	451.161	598.063	823.247	1190.538	1841.769
	Pb	492.763	534.841	584.667	644.588	718.000	810.008	928.657	1087.399	1310.529
	Pr	68.528	106.659	172.526	292.167	523.037	1002.884	2097.833	4917.949	13471.523
	Sr	1356.237	1574.165	1850.970	2210.335	2689.320	3348.655	4293.694	5720.876	8032.861
	Nd	3.351	2.454	1.748	1.206	0.800	0.506	0.301	0.165	0.081
	Zr	1483.857	1634.781	1816.309	2038.363	2315.556	2670.287	3138.610	3782.278	4716.016
	Hf	39.890	43.939	48.809	54.764	62.196	71.705	84.255	101.498	126.503
	Sm	1.853	1.731	1.607	1.482	1.355	1.226	1.094	0.960	0.822
	Eu	0.513	0.489	0.463	0.436	0.408	0.380	0.349	0.317	0.283
	Tb	0.328	0.312	0.295	0.278	0.260	0.241	0.221	0.201	0.179
	Dy	2.205	2.072	1.936	1.798	1.656	1.511	1.362	1.208	1.048
	Y	11.306	10.714	10.105	9.478	8.830	8.157	7.457	6.723	5.947
Yb	1.052	0.920	0.796	0.679	0.570	0.468	0.375	0.290	0.214	
Lu	0.102	0.078	0.059	0.043	0.031	0.021	0.013	0.008	0.004	
MS44	Element	Melt Fraction								
		0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9	0.95
	Rb	25434.132	28627.360	32735.081	38215.318	45893.021	57419.317	76650.359	115168.774	230999.726

	Ba	187961.271	211714.110	242293.284	283126.411	340392.787	426473.836	570325.739	859082.716	1730523.775
	Th	1696.553	1910.142	2184.992	2551.816	3065.956	3838.232	5127.608	7712.528	15497.521
	U	605.436	681.659	779.742	910.648	1094.126	1369.722	1829.852	2752.314	5530.488
	Nb	1136.758	1282.112	1469.505	1720.142	2072.319	2602.920	3492.202	5284.401	10728.296
	Ta	79.632	89.814	102.941	120.499	145.170	182.339	244.635	370.181	751.536
	La	272.685	319.811	383.162	472.054	604.170	817.188	1206.203	2088.098	5335.555
	Ce	461.824	565.002	710.122	924.584	1263.297	1851.042	3029.092	6064.323	19867.740
	Pb	2199.523	2476.850	2833.779	3310.248	3978.228	4981.872	6658.148	10020.409	20154.793
	Pr	66.037	85.405	114.319	160.067	238.343	387.986	727.165	1762.570	8007.130
	Sr	11933.538	13590.014	15747.745	18668.061	22828.728	29203.118	40115.162	62753.585	134849.042
	Nd	3.495E+04	9.946E+04	3.255E+05	1.279E+06	6.457E+06	4.683E+07	6.023E+08	2.205E+10	1.038E+13
	Zr	7207.807	8162.269	9398.095	11059.194	13406.779	16968.513	22990.920	35275.784	73334.707
	Hf	188.481	213.448	245.776	289.230	350.646	443.832	601.409	922.878	1918.980
	Sm	0.669	0.511	0.376	0.264	0.174	0.105	0.054	0.021	0.004
	Eu	0.339	0.288	0.239	0.193	0.150	0.110	0.074	0.042	0.016
	Tb	0.170	0.142	0.115	0.091	0.069	0.049	0.031	0.017	0.006
	Dy	0.551	0.409	0.291	0.196	0.124	0.070	0.034	0.012	0.002
	Y	6.071	5.175	4.317	3.503	2.735	2.021	1.368	0.789	0.308
	Yb	5.742E+11	2.662E+13	2.061E+15	3.123E+17	1.185E+20	1.699E+23	1.993E+27	1.084E+33	6.916E+42
	Lu	50.839	99.223	211.765	508.084	1430.463	5077.745	26001.271	259854.482	13298098.942
MS45	Element	Melt Fraction								
		0.35	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75
	Rb	2276.116	2476.309	2713.954	3000.517	3352.636	3795.410	4368.517	5138.547	6226.322
	Ba	11631.872	12998.196	14666.142	16739.770	19374.897	22814.717	27458.745	34007.241	43796.338
	Th	2056.943	2229.392	2433.294	2678.106	2977.496	3351.976	3833.803	4476.779	5377.829
	U	635.370	688.638	751.621	827.241	919.720	1035.393	1184.225	1382.834	1661.159
	Nb	351.459	382.752	419.937	464.828	520.057	589.601	679.758	801.110	972.897
	Ta	24.033	26.175	28.721	31.795	35.577	40.341	46.516	54.831	66.602
	La	1578.367	1714.247	1875.260	2069.036	2306.631	2604.680	2989.421	3504.765	4230.128
	Ce	4507.344	4892.115	5347.736	5895.651	6566.901	7408.164	8492.983	9944.304	11984.210
	Pb	328.858	357.526	391.532	432.503	482.803	545.989	627.683	737.305	891.926
	Pr	570.530	619.225	676.884	746.223	831.169	937.627	1074.902	1258.551	1516.671
	Sr	926.047	1083.497	1285.168	1549.396	1905.144	2400.362	3119.200	4220.625	6035.476
	Nd	2399.391	2603.981	2846.221	3137.500	3494.306	3941.427	4517.913	5289.037	6372.686
	Zr	15872.128	17220.792	18817.185	20736.158	23086.022	26029.555	29823.103	34894.961	42018.244
	Hf	426.797	463.052	505.966	557.550	620.715	699.835	801.801	938.120	1129.568
	Sm	487.251	528.889	578.198	637.500	710.160	801.232	918.687	1075.846	1296.779
	Eu	16.081	17.821	19.927	22.521	25.783	29.992	35.601	43.393	54.837
	Tb	48.603	52.819	57.817	63.836	71.222	80.495	92.477	108.543	131.184
	Dy	176.947	192.758	211.552	234.248	262.182	297.370	343.009	404.472	491.533
	Y	464.186	509.066	562.789	628.163	709.304	812.480	947.718	1132.064	1396.914

	Yb	28.523	31.628	35.387	40.020	45.850	53.379	63.420	77.382	97.914
	Lu	4.842	5.358	5.982	6.750	7.713	8.954	10.603	12.888	16.235
MS46	Element	Melt Fraction								
		0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8
	Rb	17896.087	39591.832	94480.747	247122.900	723962.672	2448690.938	9997032.136	52778412.928	404416796.363
	Ba	425.453	415.753	405.381	394.217	382.100	368.812	354.047	337.344	317.970
	Th	295.012	322.545	355.662	396.242	447.112	512.726	600.534	723.995	910.153
	U	91.087	99.588	109.813	122.342	138.048	158.307	185.418	223.538	281.015
	Nb	0.882	0.565	0.347	0.203	0.111	0.056	0.026	0.010	0.003
	Ta	0.070	0.048	0.032	0.020	0.012	0.007	0.003	0.002	0.001
	La	139.961	161.647	189.277	225.348	273.867	341.626	440.947	596.318	862.820
	Ce	292.160	347.630	420.547	519.076	656.790	857.602	1166.906	1679.688	2623.257
	Pb	83.537	93.136	104.921	119.691	138.679	163.872	198.699	249.563	329.858
	Pr	39.058	46.949	57.434	71.769	92.069	122.110	169.173	248.761	398.775
	Sr	70.273	60.816	51.912	43.577	35.834	28.706	22.221	16.415	11.331
	Nd	279.025	386.857	553.340	821.910	1279.137	2111.998	3767.887	7472.163	17273.143
	Zr	1967.103	2185.351	2452.299	2785.502	3211.865	3774.690	4548.138	5669.958	7426.150
	Hf	55.171	61.232	68.639	77.873	89.674	105.231	126.575	157.473	205.734
	Sm	1.885E+04	7.086E+04	3.022E+05	1.502E+06	9.017E+06	6.880E+07	7.184E+08	1.152E+10	3.436E+11
	Eu	0.636	0.560	0.487	0.418	0.352	0.289	0.231	0.177	0.128
	Tb	34.635	58.550	104.061	196.510	399.975	895.260	2269.332	6818.176	26206.663
	Dy	51.556	64.747	83.099	109.497	149.049	211.429	316.553	510.223	915.148
	Y	1.489	0.859	0.470	0.241	0.115	0.049	0.019	0.006	0.001
	Yb	24.706	28.493	33.311	39.590	48.021	59.771	76.953	103.756	149.576
	Lu	4.948	5.573	6.348	7.331	8.610	10.333	12.756	16.364	22.196
MS47	Element	Melt Fraction								
		0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9
	Rb	5569.486	6203.429	6997.911	8022.372	9392.890	11319.139	14222.196	19089.629	28904.463
	Ba	31300.085	35016.691	39696.311	45762.407	53926.727	65482.972	83048.734	112820.216	173746.427
	Th	312.314	348.542	394.037	452.839	531.715	642.920	811.152	1094.571	1669.812
	U	101.444	113.211	127.989	147.089	172.709	208.830	263.474	355.532	542.379
	Nb	219.162	247.398	283.291	330.320	394.400	486.420	628.749	875.351	1395.476
	Ta	14.786	16.691	19.113	22.286	26.609	32.818	42.420	59.058	94.150
	La	6.061	5.131	4.259	3.448	2.702	2.025	1.423	0.903	0.476
	Ce	15.793	14.723	13.612	12.454	11.239	9.954	8.579	7.084	5.407
	Pb	509.824	568.844	642.948	738.701	867.106	1048.082	1321.754	1782.572	2717.225
	Pr	1.878	1.785	1.686	1.581	1.467	1.344	1.207	1.050	0.864
	Sr	3520.266	4311.451	5408.198	6992.659	9407.264	13360.607	20525.950	35703.764	77902.955
	Nd	5.758	5.602	5.433	5.247	5.040	4.806	4.535	4.207	3.785
	Zr	2004.780	2303.794	2691.160	3209.666	3933.655	5003.524	6716.589	9817.605	16763.246
	Hf	53.045	60.978	71.259	85.026	104.259	132.696	178.260	260.813	445.934

	Sm	0.916	0.902	0.885	0.867	0.846	0.823	0.795	0.760	0.713
	Eu	0.235	0.232	0.229	0.225	0.221	0.215	0.209	0.202	0.192
	Tb	0.133	0.131	0.129	0.126	0.123	0.120	0.116	0.112	0.106
	Dy	0.963	0.945	0.925	0.903	0.879	0.851	0.817	0.776	0.722
	Y	3.797	3.748	3.693	3.632	3.562	3.482	3.386	3.266	3.105
	Yb	0.655	0.635	0.613	0.590	0.564	0.534	0.501	0.460	0.409
	Lu	0.121	0.116	0.111	0.105	0.099	0.092	0.085	0.076	0.065
MS48	Element	Melt Fraction								
		0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9
	Rb	3569.830	3984.918	4506.337	5180.462	6085.026	7360.874	9291.921	12547.126	19159.641
	Ba	21081.591	24057.356	27883.906	32963.299	39988.046	50253.029	66467.979	95321.102	158442.375
	Th	2798.303	3111.047	3502.220	4005.510	4677.101	5618.212	7031.482	9390.314	14117.254
	U	864.369	960.972	1081.802	1237.263	1444.711	1735.411	2171.957	2900.577	4360.683
	Nb	515.816	576.667	653.230	752.395	885.735	1074.262	1360.447	1844.672	2833.331
	Ta	34.993	39.128	44.331	51.071	60.137	72.958	92.427	125.381	192.703
	La	7321.311	8142.191	9169.280	10491.260	12256.098	14730.477	18448.590	24659.267	37118.560
	Ce	15861.570	17639.733	19864.547	22728.081	26550.808	31910.308	39963.496	53414.916	80398.562
	Pb	1588.208	1766.796	1990.316	2278.112	2662.472	3201.613	4012.210	5367.186	8088.076
	Pr	1658.420	1844.676	2077.762	2377.830	2778.512	3340.436	4185.085	5596.555	8429.714
	Sr	18981.273	21137.678	23839.611	27322.857	31981.484	38527.082	48388.253	64914.154	98215.658
	Nd	5706.438	6348.538	7152.244	8187.151	9569.427	11508.558	14424.414	19299.309	29090.689
	Zr	18061.530	20114.443	22686.837	26003.283	30439.125	36672.196	46063.435	61803.708	93527.362
	Hf	486.866	542.183	611.495	700.851	820.362	988.282	1241.266	1665.241	2519.628
	Sm	785.420	874.500	986.095	1129.930	1322.256	1592.409	1999.270	2680.825	4053.446
	Eu	136.777	152.480	172.178	197.605	231.662	279.597	351.964	473.561	719.480
	Tb	62.651	69.906	79.015	90.785	106.570	128.819	162.465	219.122	334.049
	Dy	208.835	233.976	265.680	306.851	362.373	441.149	561.231	765.489	1185.563
	Y	541.006	613.104	705.135	826.287	992.254	1232.089	1605.876	2259.764	3657.229
	Yb	35.006	40.467	47.586	57.183	70.694	90.850	123.499	183.471	320.518
	Lu	5.877	6.769	7.927	9.482	11.659	14.889	20.083	29.538	50.878
MS49	Element	Melt Fraction								
		0.75	0.8	0.85	0.9	0.95				
	Rb	22758.293	28532.046	38187.919	57590.243	116242.492				
	Ba	1472838.371	1843066.333	2460895.638	3698700.164	7422621.018				
	Th	1708.008	2144.020	2874.256	4344.502	8803.414				
	U	527.587	662.267	887.830	1341.975	2719.289				
	Nb	365.695	487.200	705.228	1187.721	2895.486				
	Ta	23.834	32.203	47.468	82.013	208.867				
	La	2784.870	3520.434	4762.425	7291.034	15100.175				
	Ce	6386.141	8065.710	10898.711	16658.364	34405.045				
	Pb	1453.129	1826.980	2454.262	3720.408	7576.127				

	Pr	828.045	1045.446	1411.993	2156.777	4449.477				
	Sr	96429.821	120759.363	161395.049	242903.683	488593.163				
	Nd	3320.764	4192.969	5663.683	8652.415	17854.718				
	Zr	5938.595	7768.675	10983.784	17895.177	41221.618				
	Hf	163.430	213.173	300.268	486.629	1110.872				
	Sm	622.432	787.586	1066.754	1635.984	3398.290				
	Eu	127.510	162.144	221.025	342.030	721.485				
	Tb	61.917	79.041	108.284	168.754	360.295				
	Dy	235.833	307.547	433.079	701.595	1600.521				
	Y	899.902	1258.418	1938.985	3566.092	10105.552				
	Yb	165.471	279.109	547.641	1415.999	7183.758				
	Lu	21.762	35.173	65.317	156.280	694.378				
MS50	Element	Melt Fraction								
		0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85
	Rb	16808.657	18500.704	20570.080	23158.636	26489.439	30934.578	37164.449	46521.362	62141.774
	Ba	82130.885	90697.042	101209.942	114411.332	131472.290	154355.005	186613.192	235406.396	317592.278
	Th	2262.389	2489.924	2768.175	3116.202	3563.973	4161.473	4998.744	6256.054	8354.527
	U	748.535	823.818	915.880	1031.028	1179.178	1376.867	1653.887	2069.881	2764.183
	Nb	240.949	267.599	300.501	342.095	396.255	469.526	573.865	733.623	1006.898
	Ta	17.422	19.349	21.728	24.735	28.651	33.949	41.493	53.045	72.804
	La	959.872	1061.195	1185.695	1342.243	1544.864	1817.097	2201.645	2784.730	3769.902
	Ce	1189.938	1320.571	1481.729	1685.281	1950.071	2307.889	2816.763	3594.687	4922.704
	Pb	1018.979	1122.318	1248.792	1407.124	1611.039	1883.456	2265.709	2840.669	3802.276
	Pr	93.938	104.939	118.604	135.999	158.824	189.977	234.802	304.300	425.077
	Sr	2463.005	2766.449	3145.580	3631.242	4273.139	5156.496	6439.854	8452.956	12003.504
	Nd	294.456	330.986	376.664	435.230	512.715	619.470	774.776	1018.792	1450.061
	Zr	4194.844	4648.678	5207.720	5912.629	6827.870	8061.977	9812.605	12480.600	17017.524
	Hf	111.022	123.021	137.801	156.435	180.626	213.240	259.496	329.977	449.800
	Sm	41.164	47.860	56.538	68.114	84.130	107.357	143.237	203.853	321.297
	Eu	10.126	12.027	14.547	17.993	22.899	30.247	42.038	62.893	105.724
	Tb	6.279	7.534	9.215	11.543	14.899	20.005	28.347	43.427	75.267
	Dy	39.070	47.269	58.350	73.839	96.428	131.225	188.924	295.117	524.475
	Y	211.088	258.372	323.060	414.728	550.487	763.346	1123.676	1803.678	3319.840
	Yb	22.102	28.077	36.577	49.159	68.735	101.211	159.951	280.060	576.596
	Lu	3.155	3.832	4.750	6.041	7.932	10.863	15.757	24.841	44.673
MS51	Element	Melt Fraction								
		0.75	0.8	0.85	0.9	0.95				
	Rb	28736.764	35987.067	48096.640	72386.414	145602.112				
	Ba	89563.221	114407.818	156867.782	244756.605	523616.274				
	Th	4488.301	5618.012	7503.827	11283.590	22662.716				
	U	1485.002	1858.778	2482.720	3733.295	7498.198				

	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9
Rb	4726.762	5257.376	5921.370	6776.129	7917.419	9517.870	11923.347	15942.618	24009.006
Ba	94592.855	105204.999	118483.816	135576.362	158396.676	190394.786	238482.079	318817.960	480012.410
Th	395.594	440.021	495.618	567.191	662.763	796.793	998.257	1334.915	2010.658
U	155.840	173.342	195.243	223.439	261.088	313.888	393.253	525.876	792.077
Nb	292.658	326.012	367.818	421.734	493.876	595.293	748.176	1004.591	1521.859
Ta	21.227	23.653	26.694	30.618	35.871	43.259	54.402	73.103	110.868
La	135.780	154.129	177.593	208.542	251.036	312.606	408.872	577.961	941.348
Ce	162.608	194.696	238.118	299.170	389.359	531.735	778.654	1273.219	2546.227
Pb	276.573	308.217	347.898	399.099	467.644	564.066	709.534	953.753	1447.085
Pr	180.262	330.415	650.494	1402.041	3402.345	9708.616	35034.525	183244.531	1886900.216
Sr	4588.165	5239.950	6078.786	7193.319	8736.379	10994.058	14565.850	20933.913	34902.358
Nd	2.499	2.124	1.771	1.441	1.136	0.858	0.608	0.390	0.209
Zr	939.459	1068.207	1233.132	1451.111	1751.086	2186.895	2870.512	4076.218	6682.044
Hf	26.383	29.995	34.622	40.737	49.151	61.373	80.541	114.339	187.360
Sm	0.682	0.652	0.619	0.584	0.546	0.504	0.458	0.404	0.338
Eu	0.209	0.202	0.194	0.185	0.176	0.165	0.153	0.139	0.121
Tb	0.101	0.098	0.094	0.091	0.087	0.083	0.078	0.072	0.064
Dy	0.703	0.680	0.655	0.628	0.598	0.564	0.525	0.479	0.421
Y	3.885	3.752	3.608	3.451	3.279	3.086	2.866	2.604	2.276
Yb	0.452	0.431	0.409	0.385	0.360	0.332	0.300	0.264	0.220
Lu	0.076	0.072	0.068	0.064	0.059	0.054	0.049	0.042	0.035
MS55	Melt Fraction								
Element	0.3	0.35	0.4	0.45	0.5	0.55	0.6	0.65	0.7
Rb	1875.668	2043.178	2240.947	2477.710	2765.855	3123.537	3578.419	4174.750	4987.768
Ba	11820.646	14769.889	18787.115	24402.788	32497.619	44604.918	63552.046	94936.512	150887.121
Th	34.436	37.119	40.251	43.957	48.410	53.858	60.678	69.459	81.189
U	21.725	23.418	25.394	27.732	30.541	33.978	38.281	43.821	51.221
Nb	48.578	53.406	59.162	66.124	74.695	85.467	99.359	117.859	143.538
Ta	1.849	2.036	2.259	2.529	2.863	3.282	3.825	4.549	5.557
La	57.000	62.025	67.951	75.036	83.649	94.324	107.879	125.617	149.750
Ce	68.235	75.633	84.526	95.385	108.886	126.045	148.448	178.699	221.365
Pb	157.642	170.277	185.063	202.597	223.715	249.631	282.173	324.225	380.622
Pr	7.395	8.700	10.369	12.548	15.465	19.483	25.225	33.805	47.399
Sr	1772.476	1941.148	2141.404	2382.599	2678.083	3047.552	3521.242	4147.917	5011.277
Nd	0.063	0.023	0.008	0.002	0.001	0.000	0.000	0.000	0.000
Zr	633.178	692.103	761.921	845.830	948.383	1076.280	1239.781	1455.381	1751.300
Hf	18.776	20.516	22.578	25.056	28.082	31.855	36.676	43.029	51.744
Sm	1.042	0.976	0.909	0.842	0.774	0.705	0.636	0.565	0.493
Eu	0.319	0.304	0.289	0.274	0.258	0.241	0.224	0.206	0.186
Tb	0.210	0.202	0.194	0.185	0.177	0.167	0.157	0.147	0.136

	Dy	1.505	1.441	1.375	1.307	1.236	1.162	1.084	1.003	0.916
	Y	8.136	7.784	7.420	7.045	6.655	6.249	5.825	5.378	4.905
	Yb	0.885	0.833	0.782	0.729	0.675	0.621	0.565	0.507	0.448
	Lu	0.144	0.135	0.126	0.116	0.107	0.097	0.088	0.078	0.068
MS57	Element	Melt Fraction								
		0.4	0.45	0.55	0.5	0.6	0.65	0.7	0.75	0.8
	Rb	247.723	270.493	331.309	297.844	373.189	427.108	499.110	600.093	751.898
	Ba	15990.195	17456.786	21372.583	19218.065	24068.298	27537.939	32169.819	38663.798	48421.721
	Th	21.628	23.619	28.938	26.011	32.601	37.319	43.619	52.458	65.749
	U	11.236	12.271	15.034	13.513	16.937	19.388	22.661	27.253	34.158
	Nb	34.413	37.761	46.776	41.802	53.039	61.160	72.093	87.573	111.112
	Ta	1.986	2.181	2.708	2.417	3.074	3.550	4.191	5.101	6.487
	La	47.050	52.126	66.019	58.317	75.840	88.752	106.415	131.897	171.529
	Ce	65.482	74.965	102.406	86.936	122.981	151.350	192.329	255.343	361.211
	Pb	38.533	42.140	51.800	46.480	58.470	67.078	78.601	94.812	119.270
	Pr	13.360	17.880	35.017	24.605	51.952	81.253	136.167	250.772	529.502
	Sr	2876.134	3196.044	4076.129	3587.443	4701.648	5527.673	6663.292	8311.220	10892.557
	Nd	1.693	1.356	0.812	1.063	0.601	0.427	0.288	0.181	0.102
	Zr	430.639	479.012	612.309	538.255	707.218	832.730	1005.566	1256.856	1651.394
	Hf	12.977	14.431	18.434	16.210	21.283	25.048	30.231	37.762	49.578
	Sm	0.748	0.713	0.636	0.675	0.596	0.552	0.506	0.457	0.403
	Eu	0.262	0.252	0.232	0.242	0.220	0.208	0.195	0.180	0.164
	Tb	0.129	0.125	0.116	0.121	0.112	0.107	0.101	0.095	0.087
	Dy	0.893	0.863	0.796	0.830	0.760	0.720	0.677	0.629	0.576
	Y	4.834	4.663	4.292	4.483	4.088	3.869	3.630	3.367	3.070
	Yb	0.557	0.531	0.475	0.504	0.445	0.414	0.380	0.343	0.304
	Lu	0.091	0.087	0.077	0.082	0.072	0.066	0.060	0.054	0.047
MS58	Element	Melt Fraction								
		0.6	0.65	0.7	0.75	0.8	0.85	0.9	0.95	
	Rb	10731.174	12277.288	14341.152	17234.466	21581.518	28841.564	43402.702	87287.395	
	Ba	413948.590	473589.017	553201.329	664809.166	832494.122	1112546.016	1674233.175	3367058.881	
	Th	1150.645	1316.426	1537.723	1847.957	2314.067	3092.522	4653.833	9359.347	
	U	378.234	432.729	505.473	607.451	760.669	1016.559	1529.785	3076.558	
	Nb	1440.747	1648.195	1925.087	2313.221	2896.301	3869.958	5822.368	11704.572	
	Ta	121.777	139.312	162.716	195.522	244.806	327.104	492.129	989.315	
	La	268.901	313.025	373.040	459.042	591.728	820.890	1302.123	2865.376	
	Ce	301.375	364.384	453.675	587.929	807.442	1215.485	2163.297	5795.901	
	Pb	375.525	430.419	503.842	607.013	762.457	1022.990	1548.077	3143.182	
	Pr	48.398	67.097	97.835	152.831	263.819	533.301	1438.089	7839.094	
	Sr	2852.495	3337.466	4000.726	4957.320	6444.693	9038.910	14560.608	32897.038	
	Nd	0.061	0.029	0.012	0.004	0.001	0.000	0.000	0.000	

MS59	Zr	1491.225	1738.436	2075.205	2558.686	3306.269	4601.042	7330.497	16252.815		
	Hf	41.589	48.484	57.876	71.360	92.209	128.319	204.442	453.278		
	Sm	0.634	0.575	0.513	0.449	0.381	0.308	0.228	0.137		
	Eu	0.174	0.161	0.148	0.134	0.119	0.102	0.082	0.056		
	Tb	0.113	0.106	0.099	0.092	0.083	0.073	0.061	0.045		
	Dy	0.776	0.726	0.672	0.614	0.549	0.475	0.388	0.274		
	Y	4.197	3.923	3.628	3.308	2.954	2.554	2.080	1.464		
	Yb	0.465	0.426	0.384	0.341	0.294	0.243	0.186	0.118		
	Lu	0.075	0.068	0.061	0.054	0.046	0.037	0.028	0.017		
	Element	Melt Fraction									
		0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.80	0.85	
	Rb	2411.222	2661.879	2969.400	3355.422	3854.097	4522.620	5464.528	6888.292	9284.413	
	Ba	13180.987	14705.998	16597.964	19002.565	22152.660	26443.912	32604.601	42130.498	58628.674	
	Th	1283.334	1412.652	1570.822	1768.697	2023.343	2363.228	2839.656	3555.364	4750.466	
	U	456.186	502.156	558.383	628.724	719.246	840.070	1009.434	1263.860	1688.709	
	Nb	3992.649	4393.958	4884.687	5498.433	6288.020	7341.545	8817.697	11034.132	14732.849	
	Ta	183.160	201.620	224.199	252.446	288.799	337.321	405.338	507.519	678.150	
	La	337.987	377.781	427.245	490.247	572.981	685.998	848.776	1101.459	1541.260	
	Ce	346.570	402.117	473.937	569.513	701.382	892.016	1185.422	1678.900	2629.625	
	Pb	755.690	832.830	927.301	1045.651	1198.195	1402.171	1688.694	2120.221	2843.121	
Pr	73.278	102.921	149.827	227.985	366.943	635.634	1217.367	2696.646	7518.391		
Sr	5358.420	6018.392	6842.951	7899.164	9295.094	11216.035	14006.660	18383.798	26103.181		
Nd	4.530	3.634	2.849	2.170	1.593	1.116	0.732	0.437	0.225		
Zr	2242.831	2508.112	2838.030	3258.479	3810.965	4566.236	5654.989	7346.824	10295.397		
Hf	57.387	64.213	72.708	83.542	97.789	117.283	145.415	189.187	265.598		
Sm	1.514	1.439	1.360	1.277	1.189	1.094	0.993	0.881	0.755		
Eu	0.402	0.387	0.371	0.353	0.334	0.314	0.291	0.266	0.236		
Tb	0.196	0.190	0.183	0.176	0.169	0.160	0.151	0.140	0.127		
Dy	1.291	1.244	1.195	1.143	1.086	1.023	0.954	0.876	0.785		
Y	7.039	6.773	6.491	6.190	5.865	5.511	5.120	4.679	4.166		
Yb	0.721	0.684	0.645	0.605	0.562	0.516	0.467	0.413	0.352		
Lu	0.118	0.111	0.105	0.097	0.090	0.082	0.073	0.064	0.054		
MS60	Element	Melt Fraction									
		0.1	0.15	0.2	0.25	0.3	0.35	0.4	0.45	0.5	0.55
	Rb	469.405	502.402	539.939	582.986	632.806	691.073	760.047	842.857	943.954	1069.882
	Ba	5515.512	7669.388	10879.728	15786.259	23501.630	36035.410	57177.708	94445.155	163651.551	300493.744
	Th	1569.720	1662.534	1766.980	1885.390	2020.761	2177.015	2359.382	2574.997	2833.854	3150.394
	U	509.158	539.264	573.142	611.550	655.459	706.142	765.295	835.233	919.196	1021.870
	Nb	45.875	49.183	52.953	57.285	62.308	68.195	75.181	83.588	93.880	106.738
	Ta	3.997	4.286	4.614	4.992	5.429	5.942	6.551	7.284	8.180	9.301
	La	4006.410	4243.426	4510.155	4812.554	5158.281	5557.355	6023.140	6573.869	7235.078	8043.673

	Ce	8117.668	8597.902	9138.342	9751.053	10451.554	11260.146	12203.906	13319.776	14659.498	16297.849
	Pb	276.958	293.626	312.403	333.713	358.103	386.292	419.236	458.242	505.146	562.603
	Pr	943.634	999.458	1062.281	1133.505	1214.935	1308.929	1418.636	1548.350	1704.085	1894.534
	Sr	1235.425	1313.403	1401.496	1501.779	1616.931	1750.475	1907.130	2093.367	2318.302	2595.187
	Nd	3474.104	3679.629	3910.920	4173.141	4472.933	4818.984	5222.884	5700.441	6273.799	6974.961
	Zr	10285.223	10896.287	11584.128	12364.155	13256.194	14286.187	15488.746	16911.107	18619.456	20709.478
	Hf	276.199	292.608	311.079	332.026	355.981	383.640	415.934	454.130	500.006	556.131
	Sm	673.448	713.288	758.124	808.955	867.069	934.150	1012.445	1105.019	1216.163	1352.082
	Eu	33.571	35.587	37.857	40.434	43.383	46.791	50.772	55.486	61.153	68.093
	Tb	86.693	91.824	97.599	104.147	111.632	120.273	130.359	142.285	156.604	174.116
	Dy	503.122	532.918	566.451	604.471	647.942	698.124	756.700	825.964	909.131	1010.846
	Y	2272.734	2407.473	2559.123	2731.075	2927.692	3154.682	3419.659	3733.014	4109.301	4569.561
	Yb	218.626	231.601	246.206	262.767	281.704	303.569	329.094	359.283	395.538	439.888
	Lu	32.358	34.280	36.444	38.898	41.705	44.945	48.729	53.203	58.578	65.153
MS62	Element	Melt Fraction									
		0.4	0.45	0.5	0.55	0.60	0.65	0.70	0.75	0.80	
	Rb	659.937	732.125	820.291	930.161	1070.495	1255.367	1508.829	1875.450	2447.496	
	Ba	275.764	270.627	265.110	259.142	252.630	245.444	237.403	228.231	217.487	
	Th	451.872	494.061	544.807	606.992	684.947	785.502	920.077	1109.307	1394.652	
	U	84.086	92.110	101.780	113.655	128.578	147.880	173.793	210.363	265.752	
	Nb	669.966	732.762	808.321	900.946	1017.113	1167.030	1367.777	1650.237	2076.500	
	Ta	34.669	37.960	41.925	46.791	52.902	60.802	71.399	86.341	108.948	
	La	407.215	449.145	500.045	563.052	642.931	747.280	888.974	1091.628	1403.555	
	Ce	1820.893	1995.442	2205.898	2464.471	2789.572	3210.309	3775.520	4573.806	5784.021	
	Pb	48.236	61.597	80.515	108.258	150.732	219.365	338.293	564.677	1057.123	
	Pr	279.708	306.237	338.193	377.414	426.667	490.324	575.708	696.087	878.188	
	Sr	21.192	20.976	20.742	20.486	20.204	19.888	19.530	19.115	18.619	
	Nd	1511.305	1653.032	1823.573	2032.646	2294.870	2633.300	3086.511	3724.250	4686.771	
	Zr	10292.717	11254.633	12411.761	13829.842	15607.763	17901.394	20971.421	25288.976	31800.834	
	Hf	228.349	249.800	275.615	307.268	346.975	398.233	466.891	563.532	709.438	
	Sm	575.220	628.468	692.468	770.828	868.970	995.431	1164.471	1401.829	1759.138	
	Eu	0.335	0.325	0.314	0.303	0.290	0.277	0.262	0.246	0.227	
	Tb	78.983	86.320	95.140	105.943	119.478	136.926	160.260	193.042	242.424	
	Dy	488.487	533.860	588.412	655.225	738.937	846.849	991.163	1193.916	1499.339	
	Y	1295.798	1418.904	1567.212	1749.264	1977.928	2273.522	2670.106	3229.378	4075.693	
	Yb	290.479	317.368	349.687	389.257	438.815	502.674	588.034	707.891	888.319	
	Lu	57.113	62.382	68.713	76.462	86.163	98.658	115.353	138.781	174.025	
MS63	Element	Melt Fraction									
		0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9	
	Rb	8593.605	9562.373	10775.206	12337.281	14424.211	17352.749	21757.973	29126.274	43935.070	
	Ba	184926.710	205893.751	232159.355	266011.903	311274.966	374851.003	470592.739	630962.033	953903.088	

Th	529.314	589.779	665.586	763.380	894.273	1078.351	1355.974	1821.870	2762.475
U	175.129	195.135	220.216	252.572	295.880	356.784	448.638	602.785	913.994
Nb	686.599	765.727	865.028	993.269	1165.130	1407.173	1772.860	2387.913	3633.445
Ta	49.645	55.366	62.546	71.818	84.245	101.746	128.187	172.658	262.716
La	3.513E+22	5.720E+25	2.228E+29	2.620E+33	1.310E+38	4.734E+43	3.002E+50	1.766E+59	4.046E+71
Ce	6.733	5.187	3.874	2.783	1.900	1.210	0.696	0.341	0.125
Pb	1195.015	1329.564	1497.989	1714.880	2004.596	2411.067	3022.348	4044.481	6097.902
Pr	1.113	0.906	0.719	0.554	0.409	0.286	0.185	0.105	0.048
Sr	4699.600	5281.870	6018.600	6978.875	8279.473	10134.052	12978.296	17853.563	27985.939
Nd	6.670	6.102	5.525	4.935	4.333	3.715	3.077	2.413	1.713
Zr	7602.107	8487.023	9598.761	11036.284	12965.503	15687.081	19807.211	26754.542	40872.529
Hf	191.027	213.309	241.308	277.521	326.135	394.739	498.639	673.926	1030.389
Sm	1.421	1.342	1.258	1.170	1.076	0.975	0.863	0.738	0.592
Eu	0.339	0.324	0.309	0.292	0.274	0.254	0.231	0.205	0.173
Tb	0.241	0.225	0.207	0.189	0.170	0.150	0.129	0.106	0.080
Dy	1.370	1.198	1.031	0.870	0.715	0.567	0.427	0.296	0.177
Y	6.628	6.369	6.092	5.792	5.464	5.100	4.687	4.204	3.606
Yb	0.064	0.037	0.020	0.010	0.004	0.002	0.001	0.000	0.000
Lu	8.585	12.711	19.711	32.412	57.553	113.501	260.596	760.914	3445.365

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MS65	Element	Melt Fraction								
		0.3	0.35	0.4	0.45	0.5	0.55	0.6	0.65	0.7
	Rb	3033.664	3285.099	3580.131	3930.982	4354.875	4876.858	5534.792	6388.680	7539.500
	Ba	12790.126	15758.267	19742.412	25224.039	32989.704	44384.744	61841.739	90072.001	139032.137
	Th	599.347	645.877	700.199	764.446	841.606	935.996	1054.102	1206.122	1409.078
	U	191.695	206.585	223.970	244.531	269.226	299.438	337.242	385.905	450.878
	Nb	121.082	131.435	143.615	158.138	175.737	197.480	224.987	260.833	309.373
	Ta	7.318	7.944	8.680	9.559	10.623	11.939	13.603	15.772	18.709
	La	102.119	111.909	123.542	137.562	154.752	176.265	203.874	240.440	290.880
	Ce	227.966	249.516	275.085	305.862	343.539	390.614	450.914	530.612	640.286
	Pb	44.084	48.311	53.332	59.383	66.803	76.089	88.006	103.789	125.560
	Pr	26.924	29.512	32.588	36.297	40.845	46.539	53.849	63.535	76.902
	Sr	41.767	40.040	38.255	36.405	34.480	32.471	30.363	28.139	25.773
	Nd	94.958	104.520	115.933	129.757	146.798	168.253	195.969	232.954	284.410
	Zr	3624.161	3912.863	4250.573	4650.829	5132.642	5723.554	6465.029	7422.477	8705.401
	Hf	101.223	109.285	118.716	129.894	143.349	159.850	180.556	207.292	243.116
	Sm	18.449	20.492	22.953	25.964	29.719	34.504	40.770	49.262	61.288
	Eu	0.246	0.206	0.170	0.139	0.111	0.086	0.065	0.047	0.033
	Tb	3.452	3.838	4.304	4.875	5.589	6.499	7.693	9.315	11.616
	Dy	24.387	27.010	30.160	34.004	38.778	44.839	52.744	63.403	78.414
	Y	100.134	112.994	128.746	148.370	173.314	205.796	249.366	310.019	398.601
	Yb	12.140	13.491	15.119	17.114	19.601	22.774	26.933	32.573	40.569

Lu	2.284	2.520	2.802	3.144	3.568	4.103	4.797	5.726	7.025

APPENDIX E: FRACTIONAL CRYSTALLIZATION OF BASALT

Table E1. Unnormalized trace element concentrations

	melt fraction remaining								
ppm	0.05	0.045	0.04	0.035	0.03	0.025	0.02	0.015	0.01
Rb	158.74	176.32	198.30	226.55	264.20	316.89	395.88	527.43	790.30
Ba	2515.17	2786.23	3123.97	3556.66	4131.19	4931.66	6125.39	8100.31	12010.48
Th	10.34	11.49	12.92	14.76	17.22	20.65	25.81	34.39	51.54
U	3.18	3.53	3.97	4.54	5.29	6.35	7.93	10.57	15.84
Nb	160.48	178.24	200.43	228.94	266.93	320.09	399.76	532.41	797.33
Ta	10.44	11.60	13.04	14.89	17.36	20.82	25.99	34.61	51.81
La	117.62	130.33	146.18	166.50	193.48	231.09	287.22	380.15	564.33
Ce	287.33	318.20	356.65	405.88	471.23	562.24	697.87	922.09	1365.56
Pb	12.12	13.44	15.07	17.17	19.96	23.85	29.66	39.28	58.37
Pr	42.11	46.54	52.05	59.08	68.40	81.32	100.51	132.08	194.10
Sr	2149.55	2304.51	2491.01	2720.77	3012.47	3398.11	3937.92	4762.26	6225.25
Nd	184.93	203.55	226.59	255.89	294.45	347.62	425.93	553.47	800.61
Zr	1601.29	1776.95	1996.25	2277.76	2652.47	3176.00	3959.36	5260.93	7853.02
Hf	41.36	45.91	51.57	58.85	68.54	82.08	102.34	136.00	203.07
Sm	44.55	48.64	53.65	59.96	68.16	79.34	95.53	121.38	170.11
Eu	10.14	10.88	11.77	12.87	14.27	16.11	18.71	22.67	29.73
Tb	7.09	7.69	8.42	9.33	10.52	12.11	14.38	17.96	24.57
Dy	47.01	51.11	56.11	62.39	70.51	81.49	97.28	122.23	168.63
Y	243.96	265.48	291.80	324.80	367.56	425.46	508.88	641.01	887.48
Yb	26.14	28.57	31.55	35.30	40.19	46.86	56.54	72.03	101.33
Lu	4.21	4.60	5.09	5.70	6.50	7.59	9.17	11.71	16.53

Table E2. Primitive mantle normalized trace element concentrations

	melt fraction remaining								
	0.05	0.045	0.04	0.035	0.03	0.025	0.02	0.015	0.01
Rb	249.98	277.67	312.29	356.77	416.07	499.04	623.43	830.60	1244.57
Ba	359.88	398.66	446.98	508.89	591.10	705.63	876.43	1159.01	1718.48
Th	121.65	135.14	152.00	173.67	202.56	242.99	303.60	404.58	606.40
U	151.39	168.18	189.15	216.11	252.04	302.33	377.73	503.33	754.33
Nb	225.08	249.99	281.11	321.09	374.38	448.93	560.67	746.71	1118.27
Ta	254.74	282.89	318.07	363.27	423.49	507.73	633.97	844.09	1263.60
La	171.20	189.71	212.79	242.35	281.63	336.38	418.08	553.35	821.44
Ce	161.88	179.27	200.93	228.67	265.48	316.75	393.17	519.49	769.33
Pb	170.73	189.23	212.30	241.87	281.17	335.97	417.78	553.30	822.13
Pr	152.58	168.63	188.58	214.07	247.81	294.65	364.17	478.55	703.26
Sr	101.87	109.22	118.06	128.95	142.77	161.05	186.63	225.70	295.04
Nd	136.58	150.33	167.35	188.99	217.46	256.73	314.57	408.77	591.30
Zr	142.97	158.66	178.24	203.37	236.83	283.57	353.51	469.73	701.16
Hf	133.87	148.56	166.91	190.46	221.82	265.63	331.19	440.14	657.17
Sm	100.35	109.54	120.83	135.04	153.52	178.69	215.16	273.38	383.14
Eu	60.36	64.76	70.07	76.61	84.92	95.92	111.34	134.94	176.94
Tb	65.61	71.18	77.96	86.43	97.36	112.09	133.19	166.34	227.54
Dy	63.78	69.34	76.14	84.65	95.67	110.56	131.99	165.85	228.81
Y	53.62	58.35	64.13	71.38	80.78	93.51	111.84	140.88	195.05
Yb	53.03	57.95	63.99	71.60	81.52	95.04	114.68	146.11	205.54
Lu	56.88	62.20	68.75	77.01	87.79	102.51	123.91	158.23	223.32

Fig. E1 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram of the results of fractional crystallization modeling of basalt sample G314-09-2. The trace element concentrations at differing melt fractions (5-1%) are represented by the greyscale lines with the remaining melt fractions listed in the key. The normalized trace element concentrations of low-silica rhyolite samples are also plotted (color lines). With few exceptions, the trace element concentrations are higher for the model as compared to the rhyolites. The modeled concentrations do not share the lead peak shown by the low-silica rhyolites. The model shows troughs at thorium and europium, which the rhyolites do not share. CH18 has a trough at niobium, while CH16 has a trough at tantalum; the model shows troughs at neither. The fit between the low-silica rhyolites and the model is unsatisfactory.

Fig. E2 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram of the results of fractional crystallization modeling of basalt sample G314-09-2. The trace element concentrations at differing melt fractions (5-1%) are represented by the greyscale lines with the remaining melt fractions listed in the key. The normalized trace element concentrations of A-like rhyolite samples are also plotted (color lines). With few exceptions, the trace element concentrations are higher for the model as compared to the rhyolites. The modeled concentrations do not share the lead peak shown by the A-like rhyolites. The model shows a trough at thorium, which the rhyolites do not share. The A-like rhyolites show a trough at barium not shared by the model. The fit between the A-like rhyolites and the model is unsatisfactory.

Fig E3. Primitive mantle normalized (Sun and McDonough, 1989) spider diagram of the results of fractional crystallization modeling of basalt sample G314-09-2. The trace element concentrations at differing melt fractions (5-1%) are represented by the greyscale lines with the remaining melt fractions listed in the key. The normalized trace element concentrations of Dale Tuff-like rhyolite samples are also plotted (color lines). With few exceptions, the trace element concentrations are higher for the model as compared to the rhyolites. The modeled concentrations do not share the lead peak shown by the Dale Tuff-like rhyolites. The fit between the Dale Tuff-like rhyolites and the model is unsatisfactory.

Fig. E4 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram of the results of fractional crystallization modeling of basalt sample G314-09-2. The trace element concentrations at differing melt fractions (5-1%) are represented by the greyscale lines with the remaining melt fractions listed in the key. The normalized trace element concentrations of Dale Tuff rhyolite samples are also plotted (color lines). With few exceptions, the trace element concentrations are higher for the model as compared to the rhyolites. The modeled concentrations do not share the lead peak shown by the Dale Tuff rhyolites and the inverse concentration pattern is shown at barium. The fit between the Dale Tuff rhyolites and the model is unsatisfactory.

Fig. E5 Primitive mantle normalized (Sun and McDonough, 1989) spider diagram of the results of fractional crystallization modeling of basalt sample G314-09-2. The trace element concentrations at differing melt fractions (5-1%) are represented by the greyscale lines with the remaining melt fractions listed in the key. The normalized trace element concentrations of high-silica rhyolite samples are also plotted (color lines). With few exceptions, the trace element concentrations are higher for the model as compared to the rhyolites. The modeled concentrations do not share the lead peak shown by the high-silica rhyolites and the inverse concentration pattern is shown at barium. The fit between the high-silica rhyolites and the model is unsatisfactory.

APPENDIX F: ZIRCONS AND ISOTOPIC DATING

A

B

C

D

Fig. F1 A-D. Cathodoluminescence (CL) montage images taken via scanning electron microscope, which reveal oscillatory/sector zoning typical of magmatic zircon. The bright (“active”) areas are relatively high in REE^{3+} and/or low in U, while dark (“inactive”) areas indicate the reverse. The white circles labeled 40, 35, and 25 indicate diameter in millimeters. All are shown at a magnification of 200x. All zircons were picked by hand from sample CH07a (Dale Tuff-like rhyolite).

A

B

C

D

Fig. F2 A-D. Cathodoluminescence (CL) montage images taken via scanning electron microscope, which reveal oscillatory/sector zoning typical of magmatic zircon. The bright (“active”) areas are relatively high in REE³⁺ and/or low in U. The white circles labeled 40, 35, and 25 indicate diameter in millimeters. All are shown at a magnification of 200x. All zircons were picked by hand from sample CH08a (A-like rhyolite).

A

B

C

D

E

Fig. F3 A-E. Cathodoluminescence (CL) montage images taken via scanning electron microscope, which reveal oscillatory/sector zoning typical of magmatic zircon. The bright (“active”) areas are relatively high in REE^{3+} and/or low in U. The white circles labeled 40, 35, and 25 indicate diameter in millimeters. All are shown at a magnification of 200x. All zircons were picked by hand from sample TM5 (A-like rhyolite).

Table F1. Zircon U-Pb isotopic compositions

	<u>Th</u>	²⁰⁶ Pb*	mole fraction	<u>Pb*</u>	Pb _c	²⁰⁶ Pb
Sample	U	x10 ⁻¹³ mole	²⁰⁶ Pb*	Pb _c	(pg)	²⁰⁴ Pb
(a)	(b)	(c)	(c)	(c)	(c)	(d)
CH08a						
z8 (180)	0.425	0.1216	0.9670	8.6	0.34	547
z7 (171)	0.666	0.0858	0.9354	4.5	0.49	279
z1 (39/40)	0.694	0.2455	0.9800	15.5	0.42	904
z6 (168)	0.514	0.1855	0.9743	11.4	0.41	703
z5 (101)	0.479	0.0960	0.9548	6.3	0.38	399
z2 (43/44)	0.437	0.2524	0.9686	9.1	0.68	574
z4 (104)	0.419	0.1670	0.9803	14.6	0.28	915
TM5						
z6 (188)	0.482	0.0829	0.9619	7.5	0.27	474
z5 (117)	0.461	0.2146	0.9778	13.1	0.40	815
z3 (108)	0.424	0.1980	0.9669	8.6	0.56	544
z7 (189)	0.451	0.1407	0.9775	12.9	0.27	803
z1 (54/55)	0.429	0.2917	0.9907	31.2	0.23	1933
z2 (58/59)	0.475	0.3565	0.9939	48.9	0.18	2977
z4 (128)	0.563	0.5419	0.9932	44.3	0.31	2640
CH07a						
z3 (6)	0.325	0.1702	0.9627	7.4	0.55	484
z8 (136)	0.430	0.0458	0.9298	3.9	0.29	257
z1 (1/2)	0.406	0.1160	0.9482	5.4	0.53	348
z7 (132/133)	0.431	0.1924	0.9825	16.5	0.28	1030
z5 (86/87)	0.535	0.0953	0.9474	5.5	0.44	343
z2 (3/4/5)	0.364	0.7549	0.9940	47.8	0.38	3001
z4 (88)	0.397	0.2148	0.9856	20.0	0.26	1255
MS12-49						
z9(25)	0.406	0.2218	0.9850	19.2	0.28	1199
z6(14/15)	0.389	0.3585	0.9787	13.5	0.64	857
z10(31)	0.346	0.4640	0.9730	10.5	1.06	684

z15(86)	0.351	0.0908	0.9560	6.3	0.35	410
z8(23)	0.361	0.5710	0.9877	23.3	0.59	1478
z2(7)	0.392	0.4625	0.9828	16.7	0.67	1059
z1(11)	0.347	0.8206	0.9874	22.7	0.86	1454
z4(17/18)	0.299	0.2843	0.9789	13.2	0.51	856
z14(47)	0.394	0.6815	0.9900	28.8	0.57	1807
z12(39)	0.480	1.0336	0.9953	63.9	0.40	3879
z7(12)	0.350	0.9319	0.9874	22.8	0.98	1466
z1(32)	0.426	1.0777	0.9957	68.5	0.38	4216
z20(37)	0.354	0.7854	0.9958	69.2	0.27	4346
z16(22)	0.352	1.0303	0.9953	60.9	0.40	3828
z21(50)	0.340	0.3881	0.9907	30.7	0.30	1949
z19(29)	0.395	1.1988	0.9962	76.6	0.38	4757
z18(27)	0.377	0.4491	0.9927	39.6	0.27	2482

(a) Labels for partial zircon crystals annealed and chemically abraded after Mattinson (2005); parentheses contain laser spot numbers on the same crystal, ex. Sample CH08a, zircon number 8, spot number 180.

(b) Model Th/U ratio iteratively calculated from the radiogenic $^{208}\text{Pb}/^{206}\text{Pb}$ ratio and $^{206}\text{Pb}/^{238}\text{U}$ age.

(c) Pb^* and Pb_c represent radiogenic and common Pb, respectively; mole fraction $^{206}\text{Pb}^*$ with respect to radiogenic, blank, and initial common Pb.

(d) Measured ratio corrected for spike and fractionation only. Fractionation estimated at $(0.16 \pm 0.03\%)$ / atomic mass unit for Daly analyses, based on analysis of the NBS-981 and NBS-982 Pb isotope standards.

Table F2. Zircon radiogenic isotope ratios

Sample	^{208}Pb	^{207}Pb	% error	^{207}Pb	% error	^{206}Pb	% error	correlation coefficient
	^{206}Pb	^{206}Pb		^{235}U		^{238}U		
(a)	(b)	(b)	(c)	(b)	(c)	(b)	(c)	
CH08a								
z8 (180)	0.137	0.04697	0.9	0.0320	1.0	0.004946	0.121	0.709
z7 (171)	0.214	0.04637	2	0.0313	2.2	0.004899	0.217	0.663
z1 (39/40)	0.223	0.04675	0.7	0.0315	0.7	0.004889	0.100	0.688
z6 (168)	0.165	0.04644	0.9	0.0313	1.0	0.004889	0.115	0.679
z5 (101)	0.154	0.04634	1.4	0.0312	1.5	0.004888	0.163	0.678
z2 (43/44)	0.141	0.04670	0.8	0.0315	0.9	0.004887	0.119	0.662
z4 (104)	0.135	0.04608	0.7	0.0310	0.7	0.004883	0.103	0.666
TM5								
z6 (188)	0.155	0.04640	1.8	0.0317	1.9	0.004950	0.158	0.692
z5 (117)	0.148	0.04682	0.6	0.0319	0.7	0.004949	0.104	0.676

z3 (108)	0.136	0.04685	0.9	0.0319	1.0	0.004945	0.128	0.705
z7 (189)	0.145	0.04613	0.9	0.0314	1.0	0.004945	0.110	0.718
z1 (54/55)	0.138	0.04646	0.4	0.0317	0.4	0.004944	0.079	0.745
z2 (58/59)	0.153	0.04656	0.3	0.0317	0.3	0.004944	0.078	0.698
z4 (128)	0.181	0.04656	0.3	0.0317	0.4	0.004943	0.083	0.615
CH07a								
z3 (6)	0.104	0.04673	1	0.0325	1.1	0.005037	0.130	0.697
z8 (136)	0.138	0.04649	3.1	0.0322	3.2	0.005020	0.236	0.519
z1 (1/2)	0.131	0.04636	1.5	0.0321	1.6	0.005016	0.173	0.677
z7 (132/133)	0.139	0.04678	0.5	0.0324	0.6	0.005016	0.093	0.697
z5 (86/87)	0.172	0.04659	1.6	0.0322	1.7	0.005008	0.172	0.676
z2 (3/4/5)	0.117	0.04670	0.2	0.0322	0.3	0.005002	0.073	0.764
z4 (88)	0.128	0.04562	0.9	0.0315	0.9	0.005001	0.154	0.552
MS12-49								
z9(25)	0.130	0.04662	0.7	0.0334	0.7	0.005200	0.097	0.672
z6(14/15)	0.125	0.04637	0.5	0.0331	0.6	0.005178	0.109	0.626
z10(31)	0.111	0.04678	0.4	0.0333	0.5	0.005163	0.087	0.701
z15(86)	0.113	0.04667	1.3	0.0332	1.4	0.005157	0.153	0.696
z8(23)	0.116	0.04646	0.4	0.0330	0.4	0.005153	0.112	0.610
z2(7)	0.126	0.04675	0.4	0.0332	0.4	0.005152	0.083	0.710
z1(11)	0.112	0.04672	0.2	0.0332	0.3	0.005150	0.076	0.746
z4(17/18)	0.096	0.04668	0.6	0.0330	0.7	0.005130	0.106	0.639
z14(47)	0.127	0.04673	0.3	0.0325	0.3	0.005040	0.078	0.727
z12(39)	0.154	0.04684	0.2	0.0325	0.2	0.005038	0.076	0.742
z7(12)	0.113	0.04653	0.3	0.0323	0.3	0.005033	0.084	0.637
z1(32)	0.137	0.04677	0.2	0.0324	0.2	0.005032	0.076	0.806
z20(37)	0.114	0.04672	0.2	0.0324	0.2	0.005031	0.076	0.753
z16(22)	0.113	0.04680	0.2	0.0325	0.2	0.005030	0.076	0.784
z21(50)	0.109	0.04665	0.3	0.0324	0.3	0.005029	0.082	0.676
z19(29)	0.127	0.04673	0.2	0.0324	0.2	0.005029	0.092	0.712
z18(27)	0.121	0.04687	0.3	0.0325	0.4	0.005027	0.082	0.657

(a) Labels for partial zircon crystals annealed and chemically abraded after Mattinson (2005); parentheses contain laser spot numbers on the same crystal, ex. Sample CH08a, zircon number 8, spot number 180.

(b) Calculations are based on the decay constants of Jaffey et al. (1971). $^{206}\text{Pb}/^{238}\text{U}$ and $^{207}\text{Pb}/^{206}\text{Pb}$ ages corrected for initial disequilibrium in $^{230}\text{Th}/^{238}\text{U}$ using $\text{Th}/\text{U} [\text{magma}] = 3$.

(c) Errors are 2σ , propagated using the algorithms of Schmitz and Schoene (2007).

Table F3. Zircon isotopic ages

Sample (a)	$\frac{^{207}\text{Pb}}{^{206}\text{Pb}}$		$\frac{^{207}\text{Pb}}{^{235}\text{U}}$		$\frac{^{206}\text{Pb}}{^{238}\text{U}}$		MSWD (d)	age, millions of years (e)
	$\pm$ (b)	$\pm$ (c)	$\pm$ (b)	$\pm$ (c)	$\pm$ (b)	$\pm$ (c)		
CH08a							0.78	31.426 ± 0.016
z8 (180)	48	21	32.02	0.31	31.807	0.038		
z7 (171)	17	49	31.31	0.67	31.501	0.068		
z1 (39/40)	36	16	31.50	0.22	31.439	0.031		
z6 (168)	20	21	31.29	0.30	31.438	0.036		
z5 (101)	16	34	31.23	0.47	31.431	0.051		
z2 (43/44)	34	19	31.46	0.27	31.424	0.037		
z4 (104)	2	16	31.03	0.22	31.403	0.032		
TM5							0.88	31.798 ± 0.012
z6 (188)	18	42	31.65	0.58	31.829	0.05		
z5 (117)	40	15	31.93	0.22	31.824	0.033		
z3 (108)	41	22	31.93	0.31	31.802	0.04		
z7 (189)	4	21	31.44	0.30	31.799	0.035		
z1 (54/55)	22	9	31.66	0.14	31.792	0.025		
z2 (58/59)	27	7	31.72	0.10	31.79	0.025		
z4 (128)	27	8	31.72	0.12	31.787	0.026		
CH07a							0.25	32.169 ± 0.024
z3 (6)	36	23	32.43	0.34	32.389	0.042		
z8 (136)	23	74	32.16	1.01	32.277	0.076		
z1 (1/2)	16	36	32.05	0.50	32.256	0.056		
z7 (132/133)	38	13	32.33	0.19	32.254	0.03		
z5 (86/87)	28	39	32.15	0.55	32.201	0.055		
z2 (3/4/5)	34	5	32.18	0.08	32.162	0.023		
z4 (88)	-22	21	31.45	0.29	32.159	0.05		
MS12-49								
z9(25)	30	16	33.38	0.24	33.432	0.032	0.99	32.345 ± 0.010
z6(14/15)	17	13	33.07	0.20	33.291	0.036		
z10(31)	38	10	33.26	0.15	33.197	0.029		
z15(86)	32	31	33.14	0.46	33.159	0.051		
z8(23)	22	9	32.98	0.14	33.133	0.037		
z2(7)	37	9	33.17	0.14	33.124	0.028		
z1(11)	35	5	33.14	0.09	33.115	0.025		
z4(17/18)	33	15	32.98	0.23	32.983	0.035		
z14(47)	35	6	32.44	0.10	32.407	0.025		

z12(39)	41	4	32.51	0.07	32.392	0.025
z7(12)	25	7	32.27	0.11	32.363	0.027
z1(32)	38	4	32.43	0.07	32.354	0.025
z20(37)	35	4	32.39	0.07	32.351	0.024
z16(22)	39	4	32.43	0.07	32.344	0.025
z21(50)	31	7	32.33	0.10	32.34	0.027
z19(29)	35	4	32.38	0.07	32.338	0.03
z18(27)	42	7	32.46	0.11	32.322	0.026

(a) Labels for partial zircon crystals annealed and chemically abraded after Mattinson (2005); parentheses contain laser spot numbers on the same crystal, ex. Sample CH08a, zircon number 8, spot number 180.

(b) Calculations are based on the decay constants of Jaffey et al. (1971). $^{206}\text{Pb}/^{238}\text{U}$ and $^{207}\text{Pb}/^{206}\text{Pb}$ ages corrected for initial disequilibrium in $^{230}\text{Th}/^{238}\text{U}$ using $\text{Th}/\text{U} [\text{magma}] = 3$.

(c) Errors are 2σ , propagated using the algorithms of Schmitz and Schoene (2007).

(d) Mean square weighted deviation.

(e) 95% confidence interval = $2\sigma * \text{Student's T-test} * (\text{MSWD})^{0.5}$

Table F4. C1 chondrite normalized¹ REE concentrations

Sample ^a	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
CH07a														
1	0.26	6.20	0.65	1.81	10.67	9.48	47.89	106.96	213.57	375.36	548.59	1051.64	1989.71	1407.12
2	5.96	29.38	14.94	39.63	148.32	140.03	365.53	640.45	968.07	1336.91	1706.24	2691.28	4533.02	2925.48
3	0.11	14.19	1.19	1.19	19.70	4.97	77.20	148.16	279.41	469.12	629.00	1097.07	1976.22	1175.74
4	0.89	21.18	2.09	11.49	70.89	25.34	255.68	508.79	860.11	1247.96	1693.99	2740.11	4504.04	2792.22
5	21.46	34.92	21.21	26.69	44.83	13.40	114.21	226.26	381.87	642.77	885.06	1467.66	2650.91	1744.39
6	0.46	12.60	0.74	1.57	11.68	4.74	67.53	145.90	261.80	466.71	695.42	1226.45	2236.51	1472.47
7	0.60	41.35	2.54	8.75	62.30	5.81	258.14	515.58	915.75	1314.64	1704.54	2623.90	4044.16	2400.64
8	49.51	91.61	81.03	152.11	522.69	140.42	1238.83	1928.30	2925.89	4069.62	4920.04	7167.83	9915.65	7143.97
9	1.24	81.02	8.03	24.79	137.34	18.38	368.56	590.99	967.57	1331.44	1632.14	2418.61	3843.97	2336.61
10	0.20	14.68	1.01	4.65	34.64	11.09	145.57	289.29	538.72	838.60	1166.08	2017.40	3499.47	2366.70
11	41.20	41.97	31.84	36.35	108.54	37.11	311.07	493.86	806.97	1151.27	1375.47	2160.14	3358.39	2328.36
12	42.77	50.04	34.02	42.20	57.01	10.19	119.43	224.10	383.27	554.06	804.83	1186.36	2114.37	1375.47
14	1.05	10.69	1.39	3.89	35.80	9.92	141.76	291.03	509.92	781.26	1077.62	1734.25	2922.00	1966.56
15	0.10	15.85	0.60	2.70	31.46	12.80	105.55	200.07	384.55	600.09	849.66	1412.99	2463.33	1607.42
16	0.01	14.46	0.39	2.29	25.08	8.39	94.33	213.98	388.85	611.01	887.52	1566.16	2756.66	1889.16
17	0.02	18.37	0.97	3.32	31.63	12.30	102.04	219.47	383.32	637.81	877.14	1505.24	2488.75	1703.59
69	3.91	22.39	2.53	3.17	26.44	4.39	98.49	224.96	437.84	753.98	1107.49	1896.25	3236.16	2364.93
71	1.45	56.68	2.29	6.51	62.83	12.25	244.20	508.77	987.21	1636.02	2251.85	3701.22	6311.58	4332.29
72	0.38	25.08	1.81	5.61	23.59	10.06	117.26	260.87	470.61	760.43	1152.56	1949.43	3488.57	2443.58
74	10.13	31.02	6.40	10.53	41.40	16.70	146.63	307.97	554.07	878.42	1192.71	2098.16	3610.24	2544.43
75	14.93	29.79	12.85	19.74	54.65	13.66	187.00	358.87	632.38	986.66	1362.38	2286.27	3826.50	2652.14
76	3.94	19.94	3.99	8.21	51.02	16.85	147.16	284.78	516.78	802.29	1151.51	2025.84	3585.05	2587.08
78	7.18	51.08	10.81	17.57	65.05	15.67	276.48	553.12	1092.12	1782.14	2576.33	4240.97	7572.05	4909.26
79	0.50	39.94	0.63	3.17	40.01	6.22	199.40	448.67	790.22	1249.75	1942.33	3241.17	5827.32	3707.12

80	19.21	34.20	15.23	15.77	26.96	13.47	89.66	157.45	279.45	465.90	726.77	1232.36	2172.38	1541.50
81	0.02	16.88	0.96	3.60	33.92	12.57	124.17	269.30	494.75	799.63	1125.36	1945.89	3363.29	2345.73
83	3.54	20.63	6.21	10.21	35.81	23.53	130.94	258.69	449.98	799.44	1154.22	2000.24	3617.01	2486.66
84	0.38	22.08	2.24	7.57	48.49	15.55	203.12	417.35	733.45	1186.83	1646.57	2689.83	4661.44	3132.64
85	0.47	25.74	0.81	3.32	29.99	6.04	163.92	341.80	699.24	1176.35	1826.18	3186.20	5670.96	3892.07
86	2.72	120.02	8.84	26.91	204.02	8.04	592.76	1226.36	2044.77	2950.70	3763.47	5745.16	8765.70	4716.91
87	0.85	144.70	12.83	45.38	267.29	13.65	856.02	1641.03	2685.88	3889.12	4873.97	7399.41	10766.15	6548.97
88	0.27	8.99	0.46	1.81	10.29	16.15	53.38	113.43	210.15	376.78	597.74	1185.80	2294.67	1841.41
89	0.76	43.52	9.87	31.16	208.52	114.08	587.25	1031.74	1637.56	2283.10	2944.53	4570.13	7787.74	4586.34
90	0.58	16.42	4.52	20.39	139.18	94.28	406.23	629.15	1011.05	1441.04	1902.22	2948.47	4974.50	3160.93
129	3.94	24.69	3.69	5.62	23.18	20.50	105.89	231.13	433.38	741.91	1132.31	1858.78	3068.79	2534.92
130	0.19	11.11	1.14	4.30	38.17	13.39	126.40	268.42	448.31	737.23	1095.02	1836.92	2899.02	2365.68
131	5.09	16.00	5.41	18.72	104.68	57.56	381.30	604.18	959.55	1474.45	1990.53	3104.72	4413.24	3676.92
132	17.15	24.01	17.67	18.20	57.93	19.93	172.10	307.52	527.92	827.04	1196.05	1794.83	2892.38	2588.94
133	0.02	26.20	0.92	6.51	54.88	13.45	226.04	406.24	761.45	1281.57	1835.71	2888.28	4323.56	3848.83
134	0.86	10.12	4.74	13.45	83.21	44.58	286.47	535.90	900.64	1340.19	1875.08	2851.79	4051.90	3544.45
135	7.18	22.94	3.65	11.29	55.76	19.72	200.43	437.23	735.85	1137.76	1614.19	2496.34	3820.12	3320.52
136	0.99	14.47	1.78	7.28	41.24	20.72	149.46	320.63	571.18	885.72	1226.93	1886.08	2959.31	2523.21
137	0.05	14.64	0.77	3.01	32.95	11.70	139.56	290.61	561.92	919.26	1397.89	2295.34	3633.71	3081.97
138	4.75	27.88	3.56	5.56	37.47	9.88	139.08	289.60	577.38	939.57	1476.37	2558.32	4172.02	3252.82
139	5.84	90.43	10.07	29.28	179.91	15.53	646.87	1185.14	1984.31	2866.27	3657.13	5411.35	8065.29	5348.98
140	1.63	15.32	1.80	4.65	25.33	8.47	104.63	211.89	422.31	713.16	1075.27	1825.90	3151.88	2436.47
141	44.59	269.28	108.81	209.76	806.06	347.38	2159.60	3794.41	5885.00	8313.13	10641.91	15238.72	21960.72	16187.70
143	42.98	101.52	34.50	61.09	151.54	23.68	395.97	879.53	1549.24	2506.79	3561.40	5497.66	8440.66	7061.11
145	0.01	16.09	0.37	2.25	12.48	5.34	81.32	184.90	334.29	601.43	933.14	1530.66	2466.49	2191.06
146	37.88	78.02	29.14	41.34	93.33	29.09	333.95	644.05	1133.12	1815.40	2585.80	4128.86	6261.65	5370.17
148	10.99	14.24	9.93	15.85	59.04	52.32	219.34	379.20	605.75	960.39	1358.20	2053.03	3030.77	2854.06

150	24.76	53.15	42.74	65.29	243.32	82.89	689.78	1239.66	1999.37	2897.39	3782.69	5117.06	6772.80	5751.62
151	6.89	55.74	8.02	21.29	96.38	18.08	382.61	645.97	1068.78	1493.17	2024.25	2684.46	3848.13	3022.16
153	2.85	20.19	1.82	6.18	28.99	10.69	155.63	354.57	658.38	1123.63	1785.63	2876.79	4416.69	4368.46
154	0.43	61.02	7.40	35.14	237.45	19.51	796.39	1390.09	2125.02	3058.33	4001.46	5343.63	7108.08	5786.24
156	1.08	12.43	1.38	5.89	45.36	19.56	172.76	356.25	620.97	1027.22	1523.15	2439.35	3688.92	3468.53
157	1.32	138.47	3.08	13.94	158.28	22.13	808.47	1636.26	2901.64	4703.95	6734.93	10475.79	16056.14	12947.91
158	25.67	47.39	47.79	75.09	165.91	74.24	459.67	693.71	1155.25	1678.78	2287.25	3529.03	5521.68	4337.70
159	0.07	22.44	2.91	9.69	79.90	33.37	271.22	515.74	909.55	1373.20	1986.25	3121.88	5018.64	3676.92
160	11.28	21.58	10.76	16.37	37.80	11.31	131.34	240.79	421.69	697.22	993.18	1618.09	2770.68	2165.59
161	0.36	64.38	1.38	6.88	65.26	10.57	374.61	767.67	1437.35	2351.43	3392.86	5280.84	8168.01	6541.63
162	0.97	10.84	1.04	3.87	34.46	10.66	139.21	263.13	511.56	850.28	1245.61	2002.46	3006.35	2918.33
163	0.03	24.37	1.06	5.66	43.63	15.53	211.50	452.66	787.90	1293.64	1829.17	2817.81	4307.76	3522.61
CH08a														
19	10.94	29.52	8.06	12.49	44.76	9.87	150.24	293.09	507.88	739.97	985.53	1530.35	2488.82	1596.50
21	0.03	37.01	1.30	6.45	55.04	3.53	201.71	357.69	642.08	967.70	1331.59	2047.04	3244.13	2006.07
23	0.08	42.69	2.99	8.87	64.92	12.93	277.44	533.30	886.87	1295.77	1647.31	2550.06	4029.67	2481.97
24	31.63	37.72	23.36	32.59	104.07	12.70	312.44	538.22	834.36	1266.04	1619.33	2581.67	4123.23	2408.46
25	0.02	19.00	0.93	3.73	38.19	5.01	135.72	262.98	473.61	720.59	967.97	1577.62	2447.24	1621.14
27	19.28	47.66	17.64	20.76	45.62	6.24	192.66	365.20	617.68	952.76	1208.69	1951.90	3114.64	1846.08
28	22.34	39.08	22.23	30.91	98.54	10.57	332.52	562.60	977.15	1479.59	1904.58	2880.14	4421.04	2817.19
29	444.26	369.10	330.02	364.10	301.64	13.19	322.94	412.47	625.65	961.20	1265.30	1885.42	2965.32	1874.11
30	69.98	112.17	53.97	60.32	96.85	5.04	305.04	605.45	1023.11	1541.61	1988.35	3033.03	4706.94	2974.70
31	1.50	53.78	3.57	9.45	65.32	6.17	279.30	492.68	891.62	1333.04	1782.83	2600.09	4157.48	2582.56
33	0.86	31.56	5.17	18.51	108.93	9.75	425.71	808.47	1365.13	1980.59	2569.98	3877.41	5970.38	3650.32
36	49.55	76.23	34.54	67.76	182.45	11.27	545.81	1002.43	1655.95	2473.10	3127.12	4656.99	7311.32	4486.15
37	2.24	21.10	2.30	4.71	27.38	2.67	105.60	232.71	371.89	604.85	861.56	1287.85	2095.01	1378.35

38	1.12	32.11	1.91	11.81	65.43	10.68	270.94	469.42	776.52	1281.46	1628.54	2562.57	4012.48	2458.27
39	2.33	73.76	5.17	15.68	103.05	12.42	406.27	717.23	1171.52	1704.00	2185.25	3214.94	4720.11	2944.47
40	2.02	85.63	5.53	23.18	171.30	28.22	627.58	1067.67	1647.75	2245.75	2728.20	3864.28	5682.82	3653.03
42	14.62	84.48	21.23	47.90	289.70	63.53	824.90	1351.77	2025.06	2736.28	3241.45	4715.98	6881.82	3968.72
43	15.12	38.04	11.30	20.42	71.43	6.56	238.32	389.02	720.95	1090.45	1458.16	2214.27	3411.70	2137.71
44	0.03	30.59	1.15	4.96	37.93	5.30	182.63	339.62	619.35	999.70	1310.39	2072.72	3396.83	2213.30
45	1.90	23.50	5.29	12.57	80.50	15.19	288.12	554.95	939.11	1397.13	1913.34	3035.09	4821.87	3141.32
46	0.01	26.15	0.44	5.19	34.28	5.09	148.05	278.94	537.39	823.14	1102.60	1750.65	2763.93	1823.82
47	133.64	132.66	102.74	119.86	145.06	18.91	288.20	490.71	831.95	1249.20	1645.05	2594.84	3991.76	2521.32
48	0.00	13.88	0.04	2.72	22.08	3.55	91.14	187.99	339.04	513.26	687.91	1078.86	1825.02	1183.32
92	54.92	73.66	48.03	65.05	183.24	21.14	581.62	965.20	1596.97	2287.30	2923.27	4401.02	6593.60	4292.13
93	0.10	39.48	2.66	9.36	74.26	23.15	336.22	596.40	978.91	1383.35	1698.02	2548.51	3835.63	2615.62
94	0.04	95.42	10.41	52.27	382.52	116.61	1232.76	1970.31	3025.56	3934.87	4790.79	6669.18	9652.84	6346.28
95	24.36	125.11	31.94	76.85	416.12	54.47	1319.80	2286.52	3407.97	4637.34	5679.91	8240.13	12078.33	7215.54
96	0.64	118.78	10.46	59.34	403.04	88.15	1338.67	2095.04	3180.61	4236.11	5004.86	7304.95	10704.98	6056.33
97	63.42	100.49	45.76	65.10	155.01	11.06	499.07	906.88	1538.64	2235.67	2910.75	4426.20	7108.68	4108.75
98	0.01	24.63	0.55	4.22	43.79	2.59	145.21	270.13	493.81	740.27	1053.61	1673.28	2719.23	1730.66
99	0.02	32.70	0.77	5.87	45.14	5.15	194.18	370.17	631.78	957.45	1306.91	2075.27	3118.00	2037.64
100	0.10	74.31	3.89	13.77	133.08	25.78	576.13	963.84	1555.16	2259.47	2764.11	3876.60	5668.66	3751.44
101	3.16	99.52	24.12	85.24	500.77	97.50	1530.03	2360.87	3507.48	4774.88	5693.59	7927.23	11540.31	7167.99
102	9.81	31.82	10.82	23.25	99.07	13.43	292.57	582.73	978.26	1530.45	2031.96	3107.09	5000.11	3270.53
103	13.60	67.14	14.41	24.23	89.91	8.25	341.46	642.62	1096.84	1610.67	2149.96	3320.25	5264.93	2949.78
104	16.77	41.28	11.61	17.73	46.57	3.51	174.36	296.64	538.28	825.37	1118.42	1784.67	2768.32	1728.63
105	0.85	30.61	1.45	5.41	45.02	3.65	146.51	286.13	518.86	797.63	1105.27	1787.41	2890.19	1773.63
164	24.99	82.19	20.04	33.18	115.91	7.04	467.12	871.36	1489.93	2299.04	2974.93	4380.13	6330.84	4535.40
165	27.68	56.77	25.44	37.03	94.73	9.55	325.85	592.60	1008.11	1547.97	2040.36	3018.79	4397.39	3274.98
166	0.68	23.84	3.26	10.24	78.45	8.77	283.14	559.65	966.14	1477.87	2094.19	3059.13	4458.76	3629.80

167	1.19	55.01	8.16	36.29	288.76	48.21	1042.04	1660.61	2757.77	3833.54	4916.01	6732.26	9490.70	7357.46
168	38.60	93.67	36.50	61.51	181.89	15.13	648.03	1133.76	1862.31	2742.44	3479.45	5034.19	7353.05	4910.35
169	4.03	72.84	9.47	41.94	245.15	27.92	910.59	1571.76	2518.04	3604.36	4628.67	6403.95	9150.71	6623.75
170	52.68	88.11	48.77	56.96	107.66	9.23	321.45	608.43	991.38	1502.96	2116.50	2974.38	4115.85	3314.40
171	0.12	43.04	3.54	17.70	158.64	35.52	638.02	988.08	1582.41	2225.19	2802.54	3894.18	5529.90	4086.62
172	29.37	184.07	35.53	73.82	388.87	57.02	1480.68	2495.42	3797.66	5282.36	6655.86	8465.46	11156.55	8765.56
174	17.71	46.60	17.25	20.45	71.21	5.77	236.96	428.35	741.60	1165.15	1603.21	2358.46	3491.55	2744.55
175	13.31	95.27	15.09	26.20	97.72	5.35	466.30	848.07	1486.76	2159.75	2870.58	4057.21	6061.33	4357.35
176	21.47	40.12	16.95	20.70	57.43	5.74	211.59	411.27	687.07	1067.90	1450.98	2175.86	3129.34	2598.05
177	15.98	221.00	28.14	102.16	634.36	140.25	2078.24	3279.41	4932.37	6674.44	8099.56	10609.97	13941.12	9913.94
178	0.06	64.52	2.33	9.08	68.18	3.01	362.57	713.29	1273.96	1937.10	2690.59	3924.36	5571.35	4077.85
179	19.48	97.71	19.09	37.43	137.16	6.45	564.80	1062.38	1809.13	2637.31	3455.69	5080.23	7512.99	5170.00
180	40.15	195.03	36.37	74.23	337.22	53.94	1226.41	1944.91	3105.70	4156.23	5104.81	7056.96	9774.54	6340.29
181	0.37	36.97	4.44	25.13	168.06	25.70	735.11	1269.77	2077.02	3105.63	4124.79	5656.29	7695.30	6406.86
182	16.43	129.94	26.89	77.49	450.95	188.83	1487.80	2188.01	3381.16	4529.56	5282.36	6934.38	9457.03	6995.89
TM5														
50	102.64	135.74	92.30	136.13	329.77	50.80	888.33	1492.24	2368.46	3382.65	4185.60	6124.02	9253.46	5476.17
52	505.64	440.25	420.64	497.32	540.87	72.20	849.19	1301.17	1918.11	2648.33	3378.91	4787.66	7012.18	4236.27
53	2.57	40.27	3.49	11.68	67.47	11.22	271.79	497.81	859.55	1305.66	1688.28	2477.24	3893.15	2351.43
54	0.04	54.85	1.59	9.86	86.74	11.18	359.09	730.62	1258.41	1855.32	2372.98	3622.62	5191.75	3218.69
55	648.97	569.95	617.37	705.54	730.19	64.43	1049.43	1568.04	2413.16	3325.29	4156.88	5923.08	8711.41	5292.08
56	40.19	67.72	38.73	59.31	188.45	34.62	631.32	1079.05	1808.05	2572.30	3237.58	4855.68	7240.52	4439.79
58	61.92	97.36	58.98	89.19	212.97	26.58	676.09	1178.16	1922.37	2917.24	3742.93	5381.20	8509.28	4975.23
59	0.69	28.24	1.33	4.88	53.92	6.72	247.52	431.74	772.88	1115.98	1539.38	2269.10	3591.05	2119.34
60	19.41	35.39	14.21	24.43	66.11	11.92	184.66	339.24	574.61	851.50	1127.93	1719.07	2562.86	1560.61
61	61.70	74.72	52.51	79.65	223.02	34.21	646.81	1084.05	1757.30	2471.78	3127.75	4565.81	6908.93	4131.26

62	27.68	49.42	22.82	33.93	70.00	13.35	226.16	419.21	707.25	1000.57	1325.31	1932.60	2994.71	1926.90
63	5.82	39.51	9.87	32.52	195.74	37.90	758.39	1352.57	2156.76	3070.01	3831.17	5634.01	8199.78	5248.04
64	0.02	14.14	0.71	1.90	32.82	5.64	117.13	241.83	402.71	605.48	845.93	1246.00	1999.66	1319.69
66	4.16	32.71	3.76	11.50	58.08	9.75	242.99	435.30	782.64	1120.90	1498.33	2300.07	3692.79	2043.98
67	0.23	23.24	2.03	6.51	58.03	7.45	206.45	365.81	634.69	950.20	1273.65	1861.27	2897.79	1802.75
68	0.08	51.22	4.10	16.48	139.57	19.36	535.79	968.42	1597.45	2336.56	2971.00	4413.57	6615.59	4000.63
107	156.20	192.93	135.86	175.47	225.69	22.60	497.15	847.90	1360.08	1951.31	2454.79	3632.13	5616.24	3327.26
108	56.30	108.75	50.50	83.06	248.45	39.19	690.05	1247.95	1948.30	2777.21	3607.78	5327.07	8218.89	4596.12
109	0.05	22.24	2.10	8.85	77.35	37.35	267.57	456.24	719.55	1024.17	1253.53	1916.84	2973.34	1722.16
110	82.96	96.12	69.30	93.27	164.45	24.76	450.08	798.43	1367.90	1981.89	2449.42	3663.50	5436.72	3235.97
111	5.25	9.01	8.52	20.86	144.33	103.30	362.90	620.58	979.21	1346.67	1667.64	2488.93	3753.17	2555.55
114	17.40	19.41	17.93	19.18	35.85	11.95	87.42	157.25	280.13	426.70	561.66	886.20	1469.79	885.14
115	1.94	35.99	3.88	11.04	80.95	18.59	283.56	539.42	902.90	1327.20	1664.87	2518.27	3957.67	2438.96
117	987.83	869.94	771.65	968.40	900.04	107.84	1271.61	1684.78	2493.18	3344.14	4058.49	5830.06	8588.27	4993.82
118	27.92	36.54	23.35	35.32	77.13	35.21	217.33	355.84	593.75	857.66	1043.78	1634.02	2479.98	1524.06
121	0.02	25.95	0.89	7.07	53.98	8.91	201.61	394.09	673.61	1007.22	1326.34	2054.23	3291.70	1860.23
122	13.50	98.50	12.31	31.60	163.69	15.95	669.35	1273.70	2186.36	3085.64	3939.02	5746.85	8479.37	5031.63
123	27.79	71.59	22.33	36.26	140.75	23.48	490.98	917.65	1429.28	2140.84	2597.67	4035.92	6245.75	3584.71
124	288.18	307.36	252.29	286.71	340.79	33.40	591.87	961.59	1523.43	2112.76	2687.51	4035.57	6071.67	3594.70
125	1.31	95.30	3.92	14.13	164.84	13.78	741.81	1385.43	2425.97	3548.60	4476.13	6714.03	10499.01	6210.00
126	0.01	14.21	0.50	2.68	29.47	7.86	118.54	230.15	426.69	664.58	958.30	1609.69	2630.91	1625.92
127	-	11.57	0.79	3.52	23.61	5.95	97.56	192.32	334.39	519.61	714.30	1211.68	2207.59	1420.87
128	5.19	107.74	12.29	46.63	329.39	23.53	1247.00	2239.77	3766.94	5381.28	6720.27	10031.06	14787.57	8463.58
183	0.36	42.30	2.81	13.59	106.42	25.91	440.57	845.02	1377.20	2066.06	2557.59	3802.39	5304.49	3788.03
184	277.85	222.81	176.17	221.25	333.56	104.94	855.03	1381.09	2297.85	3275.08	4138.56	5881.39	8079.76	6100.92
185	0.02	8.60	0.74	3.67	33.71	12.83	128.57	247.07	433.33	678.29	910.09	1380.89	2046.32	1599.16
187	0.09	63.29	3.38	20.02	174.51	15.79	794.52	1477.05	2502.82	3809.91	5187.70	6996.85	9291.31	7494.30

188	0.05	31.83	1.99	7.86	58.95	17.62	316.81	594.22	967.20	1437.96	1932.96	2716.48	3638.13	2938.25
189	46.37	65.37	37.53	45.42	122.21	29.22	378.42	643.16	1104.20	1661.13	2081.48	3174.86	4510.07	3213.22
191	11.30	58.52	16.53	39.75	242.14	26.03	1020.09	1902.38	3071.62	4460.76	5886.05	8114.74	10834.04	8260.41
192	10.55	52.59	14.93	25.81	123.92	18.58	472.46	864.61	1489.44	2189.02	2878.65	3846.77	5255.74	4357.99
193	2.54	36.84	9.80	34.73	209.37	40.25	827.63	1530.86	2495.57	3667.32	4806.42	6540.61	8897.91	6807.73
194	2.88	41.93	5.14	23.61	161.26	27.61	611.40	1077.44	1839.55	2598.70	3419.60	4826.59	6791.55	4730.10
195	46.63	77.37	45.80	71.47	197.40	21.14	587.72	1109.09	1804.06	2671.82	3504.24	4753.72	6436.37	5031.98
196	29.36	197.94	40.53	115.50	742.92	108.65	2482.55	4035.44	6321.18	8844.66	10983.20	14286.96	18662.14	13712.24
197	0.09	42.21	2.17	10.16	82.43	14.37	358.42	680.53	1150.75	1785.08	2353.75	3194.96	4424.12	3511.05
198	3.35	12.50	2.72	6.55	32.26	13.92	116.31	224.88	401.07	586.25	817.84	1194.26	1701.32	1334.88
199	0.40	89.26	3.77	17.04	158.48	14.99	718.91	1381.15	2315.59	3407.16	4371.35	6010.76	8083.52	6176.21
200	2.99	63.61	7.83	28.32	234.51	31.50	988.82	1704.63	2949.06	4362.93	5555.32	7663.45	10133.48	7982.60
201	160.76	156.56	134.61	189.67	325.01	46.62	888.19	1451.77	2325.53	3357.80	4431.15	5940.08	8151.75	6340.78
202	0.05	31.25	1.41	6.84	60.95	6.57	296.45	550.93	1015.06	1471.41	1961.86	2817.74	3743.08	2958.35
203	140.69	252.83	122.04	171.11	377.16	42.24	1120.72	2015.53	3266.53	4691.34	5800.07	8125.42	11656.86	7980.55
MS12-47														
1	9.05	21.19	5.59	6.32	14.62	10.97	59.64	145.37	247.65	517.23	797.29	1488.01	2565.44	2882.82
2	1.19	10.67	1.37	1.89	12.75	11.03	52.50	106.34	209.52	364.40	652.20	1224.02	2063.89	2361.98
3	1.22	10.07		1.75	17.13	16.12	51.80	140.35	250.16	475.39	880.07	1438.82	2577.97	2677.24
4		6.54		0.35	3.37	7.04	38.06	103.76	192.24	362.12	625.73	1095.99	1981.18	2247.04
5		22.11	0.26	1.18	12.77	14.51	85.89	196.27	368.41	722.57	1279.91	2130.97	3909.76	4487.77
6	0.00	9.90	0.06	1.00	6.56	5.97	56.12	101.86	223.14	381.39	745.84	1232.41	2244.16	2619.34
7		24.53	0.55	2.46	13.10	11.40	98.93	187.10	413.93	833.76	1473.04	2477.96	3919.43	4705.14
8	4.07	14.82	2.93	1.97	11.62	8.25	64.19	119.00	220.96	423.37	711.49	1241.45	2062.19	2345.84
9		15.32	0.36	1.61	9.68	9.73	79.93	154.34	341.91	639.79	1062.98	1844.83	3049.36	3703.81
10		9.70		0.58	5.68	6.06	48.12	111.31	217.66	406.06	769.70	1236.60	2099.17	2725.81

11	0.13	18.30	0.76	0.76	10.99	8.18	54.39	159.87	304.65	623.52	985.49	1702.82	2867.67	3647.55
12	0.04	51.34	1.72	6.58	66.69	7.91	373.91	724.36	1346.22	2334.33	3464.80	5230.86	7531.16	8068.55
13	0.01	20.48	0.33	1.01	9.80	12.15	104.03	209.21	405.09	755.78	1365.26	2302.02	3665.62	4291.52
14	0.02	17.86	0.88	6.22	41.35	24.21	179.76	301.64	525.55	872.54	1350.35	2086.03	3139.37	3932.08
15	3.17	21.29	1.36	6.58	41.87	27.91	166.78	332.99	532.54	911.49	1388.18	2162.52	3508.36	4044.57
16	3.96	18.70	3.42	11.37	42.25	27.03	153.90	259.12	475.78	852.07	1375.62	2151.18	3197.09	3893.97
17	0.00	13.66	0.15	1.71	18.40	6.33	70.69	141.07	280.09	535.91	930.97	1636.75	2867.86	3478.21
18		14.26	0.18	0.79	11.72	6.64	70.62	134.42	295.89	549.78	971.82	1690.13	2784.30	3442.49
19		17.97	0.41	1.82	10.90	10.12	90.48	198.68	363.05	738.69	1232.63	2081.67	3418.93	3746.65
20		24.65	0.76	3.41	26.05	1.78	187.49	392.03	726.24	1253.09	2059.95	3079.09	4895.27	4788.01
21		13.68	0.12	0.53	11.27	5.04	57.36	120.02	236.36	473.52	797.44	1399.50	2380.56	2538.86
22	0.03	33.39	1.30	3.92	26.70	4.74	166.13	396.72	725.61	1250.83	1852.22	3119.32	5079.27	4194.55
23	1.65	14.35	1.19	2.55	10.83	7.58	59.55	127.73	247.81	472.01	753.02	1348.06	2549.66	2427.87
24		10.09	0.06	0.28	9.29	8.38	49.37	94.98	218.81	391.83	610.26	1193.84	2360.19	2182.63
25	0.02	13.94	0.90	6.50	32.10	25.68	105.59	195.46	360.93	605.66	907.79	1559.88	2628.26	2292.45
26	0.47	61.22	1.81	6.46	59.61	5.76	330.11	622.06	1161.71	1912.47	2774.22	4360.60	7096.19	5636.61
27	0.02	18.44	0.68	3.80	28.80	5.84	149.43	288.04	540.51	930.46	1407.70	2319.63	3842.69	3226.21
28	0.95	26.78	1.23	2.90	28.67	18.60	122.45	238.48	450.22	768.01	1259.96	2306.52	3852.34	3400.02
29	0.03	52.82	1.00	4.89	50.18	5.77	297.66	624.70	1075.15	1791.73	2613.81	4112.54	6613.50	5282.57
30		20.11	0.34	1.50	7.24	11.93	79.44	186.68	348.32	636.19	1060.01	1955.89	3506.79	3219.92
31	0.01	16.60	0.57	1.58	15.45	15.47	57.87	135.97	270.99	516.08	866.63	1585.11	2884.56	2748.18
32	0.01	28.80	0.41	3.27	28.89	5.24	149.17	343.68	651.40	1116.59	1738.65	3119.64	4954.07	4116.26
33	0.35	20.24	1.26	2.91	16.90	4.54	65.97	183.12	304.18	604.47	1022.69	1893.31	3681.18	3174.53
34	0.01	14.80	0.45	1.08	19.75	1.39	126.61	260.54	540.76	1027.29	1518.68	2543.17	4241.86	3583.29
35		12.27	0.18	0.82	10.61	11.55	71.81	140.99	264.95	496.57	795.48	1425.96	2428.98	2192.30
36	0.02	15.30	0.90	4.21	25.35	19.62	109.79	205.12	403.12	646.06	1022.66	1680.23	3007.43	2781.71
37	0.02	37.82	0.89	3.23	34.44	5.37	199.07	390.16	738.62	1274.06	1809.70	2909.91	4609.01	3862.07

38	0.02	15.22	0.95	4.10	24.87	16.68	91.72	157.41	326.50	576.83	942.49	1673.36	3039.39	2583.62
39		14.45	0.42	1.86	31.39	3.39	160.86	335.80	638.29	1082.72	1718.86	2851.37	5049.75	4111.23
40	0.21	14.76	0.69	3.45	24.09	17.12	129.70	220.33	405.42	643.90	1000.76	1837.30	3058.80	2713.63
41	0.01	22.17	0.21	2.00	14.55	12.80	91.71	180.89	358.47	667.69	1092.50	2059.01	3741.82	3256.15
42		25.52	0.80	3.58	26.59	2.91	157.06	367.36	743.55	1226.49	1947.67	3247.63	5367.05	4272.83
43	0.05	23.87	1.96	6.90	60.20	8.36	258.26	471.15	873.20	1439.57	2249.04	3693.75	5914.74	4740.67
44	0.01	23.71	0.60	2.98	27.00	3.98	118.99	234.14	458.13	813.73	1204.71	1984.42	3303.04	2724.34
45		11.11	0.23	1.02	12.37	9.15	62.53	134.12	246.84	477.14	734.83	1436.61	2622.27	2632.08
46	0.01	42.73	0.25	4.59	43.08	3.96	248.58	507.20	960.05	1548.93	2355.59	3805.10	6076.02	5100.18
47	0.02	36.17	0.93	2.58	48.60	2.93	230.32	501.19	942.89	1619.88	2517.69	4072.98	6527.53	5340.94
48	0.48	11.71	0.35	2.02	18.60	2.26	125.04	263.64	533.83	895.19	1423.83	2570.06	4261.65	3443.47
50	0.01	22.41	0.47	1.64	22.36	2.75	124.88	271.28	501.22	791.70	1230.78	2172.10	3621.28	2878.33
51		15.90	0.23	1.02	15.15	12.82	62.71	121.12	234.52	463.21	790.54	1489.90	2793.04	2390.76
52	0.01	7.31	0.37	1.26	6.42	14.47	57.62	132.31	220.71	400.35	635.45	1158.08	2261.15	1861.60
53		10.29	0.47	2.11	16.60	15.38	89.26	160.49	348.44	649.22	1003.32	1863.65	2889.33	2837.91
54	0.02	34.10	0.83	4.11	28.68	6.32	171.57	367.57	689.53	1177.62	1732.30	2619.20	4290.93	3665.42
55	26.56	81.76	18.09	24.43	91.80	10.25	386.84	752.96	1456.27	2295.29	3262.25	5113.97	7988.61	6684.00
56		21.31	0.86	3.87	36.28	4.65	202.78	468.25	888.45	1582.28	2326.37	3808.89	6414.82	5365.36
57	0.02	39.03	0.90	6.65	57.74	5.15	278.80	500.99	944.41	1535.43	2399.06	3688.24	6064.47	4978.98
58	0.01	42.80	0.56	4.63	56.68	2.78	249.71	479.14	861.92	1461.56	2118.49	3367.40	5409.12	4529.00
59	0.02	33.03	0.88	4.30	52.78	3.05	285.40	590.26	1143.47	1921.14	2868.84	4713.43	7910.33	6522.57
60	0.03	35.08	1.17	9.90	57.86	12.62	228.74	471.57	815.97	1332.77	1934.61	3156.51	4926.02	4053.65
61	0.00	24.41	0.17	3.95	31.14	2.55	133.05	268.28	547.05	882.24	1341.89	2160.49	3554.14	2950.16
62	0.02	24.76	0.79	1.32	17.78	16.95	97.20	173.95	383.52	685.86	1043.40	1782.53	3065.58	2934.70
63	0.02	41.65	0.93	4.04	49.19	4.85	215.22	465.04	847.70	1363.47	2052.76	3161.75	4819.17	4229.26
66	0.84	42.73	2.73	8.67	51.74	22.69	229.52	498.89	894.33	1529.90	2210.98	3529.47	5771.81	4954.35
67	3.97	23.24	3.87	13.28	50.98	12.18	218.17	428.79	791.90	1342.68	2056.43	3343.12	5487.37	4859.06

68		32.60	0.84	3.77	48.23	5.33	180.98	387.74	694.20	1246.29	2100.10	3200.82	5408.90	4593.87
69		11.68	0.38	1.68	14.69	16.57	89.64	176.11	345.92	642.49	1066.89	1840.53	3145.91	3014.35
70	1.28	24.55	2.46	3.67	23.99	25.78	149.03	248.31	482.21	820.56	1303.30	2012.48	3457.66	3497.87
71	0.86	33.40	0.67	5.76	43.25	8.62	173.38	363.76	670.14	1151.20	1762.31	2829.50	4514.26	3942.07
72	0.02	12.89	0.63	4.20	30.56	21.38	99.30	175.45	315.74	519.31	816.01	1355.46	2190.17	2212.15
73	0.02	27.80	0.77	5.04	35.57	2.79	216.64	470.27	856.38	1480.97	2267.22	3630.84	5950.86	5245.69
74	0.02	32.68	0.66	2.85	25.92	21.54	134.89	315.06	610.77	1162.26	1859.49	2937.52	5205.15	5191.61
75	0.11	20.59	4.29	19.74	99.63	77.96	328.56	557.72	899.90	1456.50	2038.02	3261.02	5171.98	4351.90
76	8.28	35.24	8.26	12.80	66.63	7.70	333.95	626.24	1162.12	1968.03	2972.73	4842.46	8021.71	6494.48
77	12.69	54.49	16.43	20.43	56.27	7.44	264.49	491.17	946.66	1629.78	2422.20	4019.01	6698.36	5404.27
78	0.02	24.26	0.92	3.59	12.91	4.02	122.67	276.98	511.99	823.26	1254.72	2024.81	3502.90	2719.43
79	0.06	28.21	2.59	7.12	66.91	13.65	291.29	587.12	998.97	1778.75	2485.96	4223.18	6474.69	5370.05
80	0.01	15.04	0.37	1.25	12.35	12.49	64.35	151.37	282.17	572.13	883.40	1595.44	2913.06	2646.89
81	0.05	37.23	2.15	5.78	47.47	7.58	242.93	460.51	882.82	1464.23	2187.09	3584.94	5906.83	4861.45
82	1.37	36.50	2.84	5.68	57.04	6.06	228.95	434.02	805.07	1319.65	1858.56	3178.51	5121.15	4093.46
83	0.01	46.85	0.59	6.40	52.00	1.96	301.47	619.49	1090.52	1916.34	2772.91	4422.54	7047.95	5950.39
84	0.05	55.45	1.81	5.02	69.53	8.16	332.17	636.17	1192.71	1891.42	2691.48	4382.50	6787.13	5655.14
85	17.18	26.72	7.76	14.15	28.50	16.56	92.96	155.00	298.94	558.72	842.89	1460.61	2571.03	2332.86
86	0.01	16.81	0.49	0.85	9.52	11.42	62.46	148.39	298.20	573.17	957.56	1733.24	3074.93	2983.59
88	74.02	58.45	38.75	61.47	78.85	41.08	275.88	471.08	761.62	1222.13	1744.07	2673.88	4002.49	3459.13
89	0.20	19.98	0.83	2.22	21.53	15.63	98.78	228.90	437.98	769.10	1170.96	2063.55	3533.01	3422.14
90	0.08	48.61	0.95	5.43	53.10	5.72	269.03	570.36	1029.65	1676.63	2537.59	4125.91	6236.14	5548.10
91	0.01	37.26	0.41	5.04	37.36	27.64	207.15	380.27	673.81	1114.09	1590.24	2433.69	3876.78	3405.47
92	5.87	22.52	6.27	5.03	13.08	8.77	65.84	93.53	206.14	426.94	660.05	1166.44	2073.83	2064.38
93	11.27	31.25	7.79	9.15	40.85	4.21	142.13	400.07	742.56	1317.53	2031.64	3266.51	5696.66	4861.52
94	0.13	21.00	0.96	2.46	17.17		127.12	245.14	436.92	805.82	1205.94	2077.40	3335.54	2863.23
95	0.05	21.70	1.85	4.60	42.11	40.97	119.74	235.70	492.84	812.34	1215.47	2276.28	3920.50	3459.05

96	0.04	23.63	1.77	4.90	36.98	28.90	121.55	265.58	437.85	710.66	1147.48	1939.17	3527.64	3033.19
97	0.28	44.08	5.05	16.77	69.88	67.08	294.43	481.74	858.20	1355.40	2007.66	3295.50	6086.75	5036.76
98	0.05	67.48	1.87	5.46	75.59	7.08	323.11	695.04	1277.52	2222.21	3226.85	5140.46	8431.41	6700.46
99	0.01	34.75	0.56	3.65	26.92	7.27	178.98	383.50	733.98	1180.14	1777.41	2842.55	4577.00	3687.02
100	0.07	17.08	2.83	16.28	69.86	95.53	278.87	471.09	729.21	1206.21	1746.00	2804.50	4681.85	3780.97
101	3.35	30.05	1.48	4.02	29.42	27.15	123.52	306.13	521.95	911.31	1512.12	2646.06	4483.20	4100.83
102	0.02	13.19	0.79	0.76	12.16	11.81	61.25	134.67	220.95	423.53	711.16	1262.38	2314.02	2315.46
103	0.01	39.84	0.32	6.33	38.33	4.03	241.70	505.79	952.64	1518.23	2240.30	3568.23	5633.91	4703.39
104	0.02	44.24	0.97	3.12	57.85	4.35	280.93	536.80	975.42	1637.52	2390.12	3614.21	5805.08	5087.37
106	0.03	7.63	1.19	5.85	43.65	33.41	137.15	241.81	408.90	673.45	964.88	1632.97	2585.30	2493.86
107		22.34	0.61	2.71	21.66	2.33	134.65	265.43	525.93	880.61	1402.78	2163.74	3428.56	3092.95
108	0.03	43.84	1.05	6.05	60.76	6.04	288.09	567.85	1053.32	1749.80	2528.41	4177.65	6902.57	5620.39
109	0.01	25.54	0.55	2.17	19.59	18.96	94.92	204.70	435.38	806.68	1273.99	2249.02	4112.36	3538.58
110	0.72	30.79	1.78	4.21	37.60	4.40	164.16	339.94	600.09	1054.14	1578.09	2571.64	4199.18	3259.70
111		17.37	0.32	1.42	14.23	14.97	71.41	157.47	318.78	612.60	995.16	1839.32	3426.46	3041.04
112		9.11	0.35	1.56	8.53	13.40	63.35	102.84	205.97	381.38	685.53	1227.67	2386.61	2004.18
113	0.04	25.10	1.64	6.79	53.28	42.07	200.75	327.68	601.13	928.82	1442.35	2328.07	4011.83	3524.91
114	0.01	42.98	0.52	8.23	52.72	4.21	288.16	594.32	1106.57	1784.87	2661.76	4439.02	7626.49	6183.89
115	4.15	17.07	2.60	4.24	22.70		149.35	306.92	590.21	1014.66	1522.37	2614.91	4413.88	3886.35
116	0.30	13.44	0.65	3.03	24.98	8.26	118.65	239.58	453.40	815.54	1271.47	2171.87	3477.73	3151.31
117	0.38	10.60	1.46	3.91	34.32	27.74	156.66	290.76	496.87	784.11	1176.53	1843.04	3081.86	2709.32

Fig. F4 C1 chondrite normalized (Sunn and McDonough, 1989) REE spider diagram for zircons from sample CH07a. Values plotted here are those listed in Table 4E. Compositional data was obtained via laser ablation inductively coupled plasma mass spectrometry (LA-ICPMS). Overall, the values increase from La to Lu. The values show the greatest spread at La. There are notable peaks at Ce and Sm and troughs at Pr and Eu.

Fig. F5 C1 chondrite normalized (Sunn and McDonough, 1989) REE spider diagram for zircons from sample CH08a. Values plotted here are those listed in Table 4E. Compositional data was obtained via laser ablation inductively coupled plasma mass spectrometry (LA-ICPMS). Overall, the values increase from La to Lu. The values show the greatest spread at La. There are notable peaks at Ce and Sm and troughs at Pr and Eu.

Fig. F6 C1 chondrite normalized (Sunn and McDonough, 1989) REE spider diagram for zircons from sample TM5. Values plotted here are those listed in Table 4E. Compositional data was obtained via laser ablation inductively coupled plasma mass spectrometry (LA-ICPMS). Overall, the values increase from La to Lu. The values show the greatest spread at La. There are notable peaks at Ce and Sm and troughs at Pr and Eu.

Fig. F7 C1 chondrite normalized (Sunn and McDonough, 1989) REE spider diagram for zircons from sample MS12-47. Values plotted here are those listed in Table 4E. Compositional data was obtained via laser ablation inductively coupled plasma mass spectrometry (LA-ICPMS). Overall, the values increase from La to Lu. The values show the greatest spread at La. There are notable peaks at Ce and Sm and troughs at Pr and Eu.

Table F5. Ti-in-zircon formation temperatures

Sample*	°C	Sample*	°C	Sample*	°C	Sample*	°C
CH07a		CH08a		TM5		MS12-47	
1	711	19	681	50	693	1	659
2	661	21	655	52	763	2	708
3	1104	23	697	53	715	3	692
4	823	24	757	54	672	4	653
5	779	25	656	55	697	5	687
6	720	27	670	56	701	6	664
7	703	28	679	58	653	7	687
8	704	29	662	59	666	8	720
9	791	30	676	60	1140	9	747
10	687	31	657	61	719	10	682
11	731	33	628	62	672	11	671
12	710	36	653	63	747	12	649
14	673	37	661	64	681	13	711
15	693	38	677	66	742	14	700
16	1203	39	688	67	697	15	676
17	759	40	788	68	716	16	741
69	838	42	723	107	729	17	698
71	658	43	675	108	672	18	691
72	673	44	659	109	847	19	719
74	668	45	756	110	721	20	631
75	643	46	668	111	1885	21	695
76	761	47	693	114	772	22	660
78	696	48	664	115	708	23	686
79	670	92	737	117	722	24	667
80	708	93	698	118	735	25	732
81	697	94	666	121	849	26	656
83	687	95	664	122	665	27	661
84	612	96	738	123	782	28	727
85	696	97	644	124	669	29	659
86	829	98	671	125	663	30	721
87	701	99	727	126	683	31	707
88	667	100	753	127	704	32	656
89	714	101	701	128	718	33	731
90	791	102	776	183	681	34	616
129	743	103	626	184	668	35	729
130	672	104	645	185	676	36	683
131	765	105	669	187	657	37	638
132	654	164	661	188	714	38	785

133	676	165	680	189	634	39	576
134	771	166	659	191	779	40	791
135	843	167	709	192	697	41	748
136	705	168	671	193	703	42	648
137	652	169	694	194	697	43	645
138	700	170	659	195	722	44	682
139	677	171	738	196	654	45	679
140	657	172	736	197	684	46	659
141	799	174	667	198	681	47	611
143	711	175	670	199	696	48	658
145	643	176	696	200	724	50	644
146	727	177	781	201	672	51	726
148	836	178	657	202	609	52	687
150	1655	179	654	203	649	53	758
151	732	180	991			54	671
153	691	181	799			55	672
154	694	182	773			56	621
156	710					57	667
157	752					58	667
158	881					59	641
159	668					60	677
160	663					61	640
161	656					62	714
162	694					63	661
163	685					66	756
						67	723
						68	676
						69	739
						70	679
						71	658
						72	750
						73	631
						74	769
						75	759
						76	654
						77	672
						78	636
						79	637
						80	768
						81	667
						82	721

83	654
84	682
85	708
86	692
88	754
89	734
90	682
91	738
92	710
93	701
94	656
95	721
96	715
97	761
98	658
99	675
100	745
101	804
102	739
103	657
104	668
106	733
107	679
108	667
109	743
110	690
111	734
112	683
113	765
114	636
115	776
116	668
117	740

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* Laser spot numbers. Spots with data that was incomplete or judged to be unusable due to sampling error (i.e. laser burning through zircon, hitting an inclusion) were removed.

Table F6. $^{40}\text{Ar}/^{39}\text{Ar}$ age dating

	$40(a)/36(a) \pm 2\sigma$	$40(r)/39(k) \pm 2\sigma$	Age (Ma)	$\pm 2\sigma$	MSWD	$^{39}\text{Ar}(k)$ (%,n)	K/Ca	$\pm 2\sigma$
Age Plateau		10.41868	± 0.08699	32.66	± 0.36	91.75	86.96	$\pm$
Error Mean			$\pm 0.83\%$		$\pm 1.09\%$	0%	5	± 3.8
			Minimal External Error		± 0.63	2.41	2 σ Confidence Limit	
			Analytical Error		± 0.27	9.5787	Error Magnification	
Total Fusion Age		10.19654	± 0.00949	31.97	± 0.23		8	$\pm$
			$\pm 0.09\%$		$\pm 0.71\%$		9.7	± 0.2
			Minimal External Error		± 0.56			
			Analytical Error		± 0.03			
Normal Isochron			± 0.13330	33.04	± 0.48	69.67	86.96	
No Convergence	218.54	10.53987	$\pm 1.26\%$		$\pm 1.44\%$	0%	5	
	± 73.06		Minimal External Error		± 0.71	2.63	2 σ Confidence Limit	
	$\pm 33.43\%$		Analytical Error		± 0.41	8.3471	Error Magnification	
						500	Number of Iterations	
						6.80885E-05	Convergence	
Inverse Isochron			± 0.12564	32.95	± 0.45	65.31	86.96	
Error Chron	234.13	10.51273	$\pm 1.20\%$		$\pm 1.38\%$	0%	5	
	± 67.83		Minimal External Error		± 0.69	2.63	2 σ Confidence Limit	
	$\pm 28.97\%$		Analytical Error		± 0.39	8.0817	Error Magnification	
						7	Number of Iterations	

5.24E-08	Convergence
8%	Spreading Factor