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**TECTONOMETAMORPHIC HISTORY OF THE NOWYAK COMPLEX, NUNAVUT,
CANADA**

by

MARIA M. TERMEER, B.Sc. (Hons.)

**A thesis submitted to
the Faculty of Graduate Studies and Research
in partial fulfillment of
the requirements for the degree of
Master of Science**

Department of Earth Sciences

Carleton University

Ottawa, Ontario

August, 2000

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TECTONOMETAMORPHIC HISTORY OF THE NOWYAK COMPLEX,
NUNAVUT, CANADA

submitted by Maria M. terMeer, B.Sc. (Hons.),
in partial fulfillment of the requirements for
the degree of Master of Science.

Chairman, Department of Earth Sciences

Thesis Supervisor

Thesis Supervisor

Carleton University

May, 2001

ABSTRACT

The ductile, top-down-to-the-north, Nowyak shear zone separates greenschist-facies metavolcanic rocks (hanging wall) from mid-amphibolite facies metagranite containing supracrustal enclaves (footwall). U-Pb ion-probe data for a metapelitic enclave indicate ca. 1.82 Ga matrix monazite, and either a reset Archean or a Proterozoic detrital zircon population (1780 ± 132 to 2194 ± 49 Ma (1s)). Enclave assemblages record a M1 clockwise P-T path through $\sim 660^\circ\text{C}/12.4$ kbar. The interpretation of both monazite and M1 assemblages as syn-tectonic with the main foliation points to ca. 1.82 Ga crustal thickening and exhumation, followed by post-tectonic garnet breakdown (M2= $565^\circ\text{C}/6.1$ kbar) during ca. 1.82 Ga granite plutonism. ^{40}Ar - ^{39}Ar cooling ages for hornblende, muscovite, and biotite range from ca. 1775 to 1804 Ma, 1746 to 1748 Ma, and 1740 to 1780 Ma, respectively. The survival of ca. 2.64 Ga U-Pb titanite ages in the metagranite is consistent with studies that have documented minimal resetting during high-temperature deformation.

ACKNOWLEDGMENTS

This project was carried out at the Geological Survey of Canada and at Carleton University under the supervision of Dr. Rob Berman and Dr. Sharon Carr. Funding for this project was made available by DIAND, an NSERC research grant to Rob Berman, and a scholarship and TA funding from Carleton University to the author. Firstly, I would like to thank Rob Berman and Sharon Carr for their excellent supervision throughout the course of this project. Their advice, support and guidance have been invaluable to me the past 2 years. Carolyn Relf, Kate MacLachlan, and Doug Irwin are thanked for their help in the field, and in the writing of this thesis. I am grateful to Hamish Sandeman for his invaluable advice with respect to ^{40}Ar - ^{39}Ar data, and Bill Davis for his assistance with U-Pb geochronology. Discussions with various members of the NATMAP Western Churchill project were instrumental to the development of this thesis, and are gratefully acknowledged.

I thank Pat Hunt for providing expert SEM assistance and X-ray maps, Richard Stern for help with SHRIMP instrumentation, Katherine Venance and Peter Jones for their time in helping me obtain excellent microprobe data, Mike Jackson for providing first-class thin-sections, Leif Bjornson for photography advice, Chris Rogers for computer guidance, and Stacey Turner for assistance in obtaining ^{40}Ar - ^{39}Ar and Ca/K plots.

A huge thank you goes to Chris Studdnicki-Gizbert and Brad Harvey, for their support and assistance in the field, and for sharing with me their unique senses of humor (Ring-bottoms, anyone?). Many thanks goes towards the students and faculty of Carleton university, most of who are too numerous to list here. In particular, I would like to thank the Mike's lunch crowd for always lifting my spirits, Tanya Tettelaar and Sarah McMullen for their zany attitude to life (and for reviewing chapter 6), and my office-mates in Steacie 237 (plus the chipmunk who kept me company in Tory 246) are thanked for providing me with stimulating conversation and lots of laughs. And finally, a special thank you goes to Andrea Mills for her listening skills, counsel, and friendship - your support sustained me through difficult periods, and I look forward to many good times in the future.

Most importantly, I would like to thank my parents and my sisters for their love and prayers. They taught me that:

*Your thoughts become your words
Your words become your actions
Your actions become your habits
Your habits become your character
And your character becomes your destiny*

ORIGINAL CONTRIBUTION

This research focused on further understanding the timing and conditions of metamorphic events within the Nowyak complex (Western Churchill province). It is a multidisciplinary study that employs a number of techniques, including petrography, geothermobarometry, and ^{40}Ar - ^{39}Ar and U-Pb geochronology. I was directly involved in sample collection, preparation, and data analysis, however expert advice from specialists was utilized.

I collected petrographic, geochronologic, and thermobarometric samples during the summer of 1998. Fifty thin sections, encompassing rock units from the Nowyak complex and surrounding wallrock, were made at Carleton University by M. Jackson, and were subsequently examined by myself for metamorphic textures and shear-sense indicators. From this group, 12 samples were chosen for geothermobarometry. Scanning electron microprobe images, taken in backscatter and cathodoluminescence mode, were produced with the assistance of P. Hunt at the Geological Survey of Canada (GSC). I assisted P. Jones (Carleton University) and K. Venance (GSC) with electron microprobe analysis. I conducted all data reduction and interpretation, under the guidance of R. Berman.

I prepared geochronology samples for ^{40}Ar - ^{39}Ar analysis. Cleaning, crushing and sieving of all rocks samples, and picking of hornblende, biotite, and muscovite was performed at the GSC, under the supervision of H. Sandeman. Step-heating and analysis of samples were performed by H. Sandeman at the GSC. Ca/K and ^{40}Ar - ^{39}Ar plots of the data were produced by H. Sandeman and A. Turner. I interpreted all ^{40}Ar - ^{39}Ar data with the assistance of H. Sandeman.

A rock puck of sample BLB97-005, containing zircons for in-situ analysis, was prepared by Rob Berman and Bill Davis at the GSC. U-Pb data was collected using the SHRIMP II at the GSC by myself, Rob Berman, Bill Davis, and Richard Stern. I interpreted the U-Pb data, in conjunction with Rob Berman and Bill Davis.

I wrote and compiled all chapters, appendices, tables, and the majority of figures in this thesis. Chapters from this thesis benefited from pre-defense readings by H. Sandeman, B. Davis, and S. McMullen. The thesis, in entirety, was critically reviewed by R. Berman, S. Carr, R. Kretz, J. Blenkinsop, and J. Cheetham. Their suggestions are gratefully acknowledged, and when possible, have been incorporated into this thesis.

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CHAPTER ONE: INTRODUCTION AND OBJECTIVES

CHAPTER ONE: INTRODUCTION AND OBJECTIVES

Preliminary geochronology within the Western Churchill NATMAP region has revealed a complex polymetamorphic history, with tectonothermal events at ca. 2.57, 2.50, 1.91, 1.83, and 1.75 Ma. Interpretation of the tectonic significance of these events is hampered by the limited recognition of structures associated with crustal thickening and exhumation.

The Nowyak complex (Map 1), located ~350 km southwest from Rankin Inlet, is a domain of mid-amphibolite facies rocks exposed in the core of a structural antiform, and may represent a potentially important extensional domain within the Western Churchill Province. It is separated from greenschist-facies metavolcanic rocks by the Nowyak shear zone, a shallow, north-plunging zone of intense shear. This study addresses the timing and sense of displacement of the shear zone, and attempts to define quantitative P-T paths for the Nowyak complex and its surrounding rocks, in an effort to determine the role of Archean and Proterozoic events within the complex.

Two weeks in the summer of 1998 were spent collecting structural data and collecting samples for petrography, geothermobarometry, and geochronology analysis. Petrology and kinematic analysis of 50 thin sections were performed to distinguish the timing of metamorphism with respect to deformation, and to attempt to distinguish among the 3 main generic models (shear-fold, metamorphic-core, or diapiric emplacement) suggested for the Nowyak complex (Chapter 2, 7).

Geothermobarometry was performed to allow for a comparison between metamorphic events recorded within the Nowyak complex and within the hanging wall.

U-Pb geochronology analysis of zircon and monazite within the Nowyak footwall was attempted to pin down the timing of metamorphism with respect to the main deformational event. ^{40}Ar - ^{39}Ar ages for hornblende, muscovite and biotite were analysed in an effort to determine cooling rates associated with the high-pressure metamorphic event.

This study attempts to resolve the apparent contradiction between syn-deformational emplacement of the Nowyak metagranite at ca. 2.64 Ga (zircon and titanite; MacLachlan et al., in preparation, 2001) and ca. 1.82 Ga monazite and possibly garnet growth (Berman, personal communication, 2000). Results should help to elucidate Archean and Proterozoic metamorphic and deformational events throughout the Western Churchill Province.

CHAPTER TWO: REGIONAL GEOLOGY AND PREVIOUS WORK

FIGURES:

Figure 2-1: Regional geology of the Western Churchill Province

Figure 2-2: Regional geology of the Yathkyed Lake-Kaminak Lake area

CHAPTER TWO: REGIONAL GEOLOGY

2.1 Introduction

The Western Churchill Province of northwest Laurentia is an Archean basement complex comprised of granite-greenstone terrains, or high-grade equivalents, overlain by the erosional remnants of an Early Proterozoic sedimentary cover (Figure 2-1; Hoffman, 1988). It has been variably reworked in the Proterozoic during both the Thelon and Trans-Hudson orogenies, respectively (Hoffman, 1988; Bickford et al., 1994). The ca. 2.02 - 1.91 Ga Thelon orogen resulted from the dextral-oblique collision between the Slave and Rae provinces, whereas the ca. 1.91 - 1.81 Ga Trans-Hudson orogen involved the Hearne and Superior provinces (Hoffman, 1988).

Traditionally, the Western Churchill Province has been divided into the Rae and the Hearne sub-provinces along the Snowbird Tectonic Zone (STZ; Hoffman, 1988). The STZ occurs as a pronounced linear anomaly, over 1500 km in length, on the Bouger gravity map of the Canadian Shield (Hoffman, 1988; 1990; Bickford et al., 1994). Exposed segments have been previously mapped as the Virgin River (Wallis, 1970; Lewry and Sibbald, 1977) and Black Lake shear zones (Hanmer et al., 1990; 1991) in Saskatchewan, and the Tulemalu fault zone in the NWT (Tella and Eade, 1980, 1986; Tella et al., 1981).

The origin of the STZ is enigmatic, and a number of hypotheses have been proposed. It may represent the limit of penetrative tectono-thermal influence of the Trans-Hudson orogeny (Lewry et al., 1985). In this scenario, the location of the STZ may

have been controlled by lateral rheological variations, due to the existence of a thermal dome within the Trans-Hudson hinterland (Lewry et al., 1985).

The STZ may also represent a Paleoproterozoic suture between the Rae and the Hearne provinces formed during the final assembly of Laurentia (Thomas and Gibb, 1985; Hoffman, 1988). This is based on regional geophysical data that suggests that the STZ truncates the Proterozoic Taltson magmatic zone (southern extension of the Thelon orogen), and is supported by geophysical data along the southwestern extension of the STZ in Alberta (Ross et al., 1991).

Ross et al. (1995) interpreted structures in a seismic-reflection profile as a major buried orogenic belt associated with crustal-scale thrust imbrication, and suggested that imbrication in the Alberta basement was coeval with deformation in the Trans-Hudson orogen to the east. This implies that the area underwent considerable shortening during the Paleoproterozoic (ca. 1.8 Ga). Proterozoic activity is also documented in the Chesterfield Inlet segment of the STZ, where anorthosite-gabbro emplacement and deformation in the granulite-facies Kramanituvar Complex has been dated at ca. 1.9 Ga (Sanborn-Barrie, 1994).

Finally, the STZ may represent an Archean intercontinental fault which was reactivated either during collision of the Slave craton with the Rae province or during assembly of Early Proterozoic magmatic arcs along the western margin of the Rae province (Carolan et al., 1989; Lewry and Collerson, 1990). Support for this hypothesis comes from detailed structural mapping and preliminary geochronology (Hamner et al., 1991; 1992; Hamner, 1997) in the Striding- Athabasca mylonite zone. Deep-crustal,

regional-scale pure shear under medium to high pressure granulite facies occurred at ca. 3.2 and ca. 2.6 Ga (Hamner et al., 1995), and is interpreted to indicate principal deformation of the STZ in a late Archean intracontinental setting. This interpretation is supported by regional similarities, such as Nd model ages, between the Rae and Hearne provinces since ca. 2.6 Ga (Baldwin and Bowring, 2000; Hamner et al., 1995).

2.2 Regional Geology of the Western Churchill Province

The Rae and Hearne provinces share many similarities including Late Archean greenstone belts and associated granites (Hoffman, 1988). The Rae province contains ca. 2.8 Ga ultramafic-mafic-felsic volcanics (Schau, 1982), and ca. 2.95 – 3.33. Ga granite occurs on the Melville Peninsula (Wanless, 1979), near Baker Lake (Hoffman, 1988), and at Lake Athabasca (Van Schmus et al., 1986). The Hearne province contains ca. 2.7 Ga submarine mafic-intermediate-felsic volcanics and associated greywackes (Davidson, 1970), and ca. 3.48 Ga gneiss that occurs approximately 200 km northeast of the Athabasca basin (Wanless, 1979). Both provinces preserve Early Proterozoic erosional remnants of sedimentary cover that predate ca. 1.85 Ga (Hoffman, 1988). The Hurwitz Group of the Hearne province and the Amer Group of the Rae province have been correlated across the STZ (Hoffman, 1988). They both consist of orthoquartzite in the lower part, overlain by a mixed carbonate, pelite, and mafic volcanic succession in the middle of the groups, which in turn is overlain by an upper part dominated by fine-grained feldspathic sandstone (Hoffman, 1988).

Although the Churchill province has traditionally been divided into the Rae and Hearne sub-provinces along the STZ (Hoffman, 1988), recent geochronology and

geochemistry carried out during the course of the western Churchill NATMAP project suggest that the STZ may not represent a significant tectonic boundary (Sandeman et al., 2000; Davis et al., 2000). Researchers involved with the Western Churchill NATMAP project, an integrated geochemical, geochronological, structural, and metamorphic study in the Western Churchill Province (north and west of Hudson Bay), have subdivided the Hearne province into the northern Hearne and central Hearne domains on the basis of: (1) lithological associations and geochemical signatures of late Archean supracrustal belts (Sandeman et al., 2000), (2) distribution of late Archean granitoids, and (3) the superposition of Paleoproterozoic events (Relf and Hamner, 2000; Davis, 2000). Overlying the Rae and central Hearne domain are the Amer and Hurwitz Group. The Hurwitz Group is interpreted to be a stable, intracratonic basin which may have formed during the assembly of Laurentia (Aspler et al., 2000). During the Proterozoic, two suites of granitoid plutons were emplaced in the Western Churchill: (1) ca. 1.81 - 1.85 Ga Hudsonian granites, which generally occur throughout the Hearne and within the eastern part of the Rae province, and (2) ca. 1.75 Ga Nuelin granites, which occur in the southwestern part of the Hearne domain and in the western part of the Rae province (Peterson et al., 2000).

2.2.1. Rae Province

The best studied greenstone belt in the Rae province is the Woodburn Lake greenstone belt. The Woodburn Lake greenstone belt may be correlative with similar supracrustal assemblages, including the Prince Albert Group, the Mary River Group on Baffin Island, and the Murmac Bay Group in northern Saskatchewan (Zaleski et al., 2000;

Ashton et al., 2000), forming a discontinuous northeasterly trending zone more than 1000 km in length (Zaleski et al., 2000). It forms part of a diverse volcano-sedimentary package, including extensive and well-preserved komatiites and basaltic volcanic rocks intercalated with felsic volcanic rocks and quartzites (Zaleski et al., 2000). Metamorphic grade throughout the belt varies from greenschist to amphibolite facies. Volcanic rocks are interpreted to represent two cycles of volcanism at ca. 2.72 and 2.71 Ga, and Neoarchean komatiites are interpreted to have been generated via cyclic processes, possibly linked to mantle upwelling impinged on both continental and oceanic crust (Zaleski et al., 2000). The Woodburn Lake greenstone belt likely formed in a geodynamic setting distinct from the greenstone belts of the northern and central Hearne domains (Zaleski et al., 2000; Sandeman et al., 2000).

2.2.2 Northern Hearne domain

The northern Hearne province (Figure 2-1) is generally thought to lie immediately southeast of the Snowbird Tectonic Zone, and includes the Angikuni, MacQuoid-Gibson, and Yathkyed Lake greenstone belts (includes the Nowyak complex). Angikuni Lake straddles the central segment of the STZ, and comprises 7 lithostructural domains. Angikuni is cut by a network of branching shear zones, interpreted by Aspler et al. (2000) to represent a positive flower structure. Domains 1 and 3 are greenschist- to amphibolite-grade ca. 2.69 to 2.68 Ga supracrustal rocks, and include mafic to intermediate tholeiitic volcanic rocks (Aspler et al., 2000). The remainder consist of upper amphibolite-facies gneiss and variably deformed gabbroic to granite intrusions. Aspler et al. (2000) suggested intracratonic transpression at ca. 2.62 to 2.61 Ga, but recent geochronology

indicates a major high-grade metamorphic event occurred at ca. 2.54 Ga and 1.90 Ga (Berman et al., 2000).

The MacQuoid-Lake greenstone belt occurs as a northeast trending linear belt, composed of supracrustal belts and associated plutonic complexes, and is interpreted to represent a portion of reworked Archean craton (Tella et al., 2000). The belt is broadly divided into two lithological and structural domains, the MacQuoid homocline, and the Cross Bay plutonic complex (Tella et al., 2000). The MacQuoid homocline is a northwest dipping belt composed of Archean amphibolite-facies sedimentary rocks and gneiss in the south, structurally overlain by ca. 2.68 - 2.72 Ga amphibolite-facies mafic, intermediate, and felsic volcanic rocks and associated 2.66 - 2.68 Ga plutonic rocks to the north and west (Tella et al., 2000). Structurally overlying the MacQuoid homocline, the ca. 2.7 Ga Cross Bay plutonic complex is composed of Archean tonalite gneiss, diorite, and gabbro, and has been interpreted to have been deformed at ca. 2.69 Ga, before the onset of volcanism in the MacQuoid homocline (Tella et al., 2000). The belt has experienced multiple metamorphic events, including: (1) ca. 2.50 - 2.56 Ga Archean metamorphism, which ranged from ~5.5 kbar/600 °C in the SW to 9 kbar/750 °C in granulite complexes to the NW, (2) ca. 1.9 Ga high-pressure metamorphism, which ranged from 10 kbar/700 °C in the SW to > 12 kbar/800 °C in the NW, and (3) widespread greenschist to lower-amphibolite facies metamorphism interpreted to be associated with intrusion of 1.83 Ga granite plutons (Tella et al., 2000).

The Yathkyed belt preserves late Archean structures and metamorphism within two structural levels (Figure 2-2). The upper tectonostratigraphic unit, composed of upper

amphibolite facies assemblages, records peak metamorphism and deformation at 2.57 - 2.49 Ga (Berman et al., 2000; Relf et al., 1999; MacLachlan et al., 2000). Supracrustal rocks of the upper tectonostratigraphic unit include a package of mixed volcanic and associated volcanoclastic rocks, and psammitic to pelitic sedimentary rocks (Relf et al., 1999). The lower tectonostratigraphic unit, comprising lower amphibolite to greenschist-facies assemblages, preserves evidence for pre-2.62 Ga metamorphism and foliation development, and consists of amphibolite and biotite-monzogranite (Relf et al., 1999; MacLachlan et al., 2000).

The central and northern portions of the Yathkyed belt have escaped the extensive Proterozoic reworking experienced by the majority of greenstone belts within the Western Churchill Province. The lack of Proterozoic reworking within the Yathkyed Lake greenstone belt is indicated by K-Ar ages for hornblende in the upper tectonostratigraphic unit that are as old as 2.47 Ga (Eade, 1986; Loveridge et al., 1988), and the lack of evidence for high-pressure, ca. 1.9 Ga metamorphism (Berman et al., 2000).

In general, the northern Hearne domain is characterized by Th and LREE-enriched incompatible element patterns with negative Nb, P, and Ti anomalies (Sandeman, 2000). Sandeman (2000) suggested that the majority of the Hearne province represents juvenile, Neoarchean oceanic crust, and proposed that the northern Hearne developed near an older continental crust, possibly in an back-arc setting. Magnetotelluric data have been interpreted to indicate that the northern Hearne domain may be underlain by the Rae province (Jones et al., 2000). Current data allows the northern Hearne domain to have experienced a separate Neoarchean tectonometamorphic history at 2.6 - 2.5 Ga relative to

other regions in the Hearne (Davis et al., 2000), although this may be an artifact of the greatly expanded geochronological database for this part of the Hearne province.

2.2.3 Central Hearne domain

The central Hearne domain includes the southern Henik-Kaminak-Tavani greenstone belt. The Kaminak greenstone belt is a 500 km long segment of the Ennadai-Rankin greenstone belt, an assemblage of supracrustal sequences within the Hearne domain, grouped together by Aspler and Chiarenzelli (1996). Davidson (1970) mapped and defined the belt as an assemblage of Archean supracrustal and volcanic rocks, and later mapping by Hamner et al. (2000) demonstrate that both stratigraphy and deformation history vary significantly along the length of the belt.

The Kaminak greenstone consists of 2.70 - 2.68 Ga volcanoclastic rocks, intruded by ca. 2.69 - 2.68 Ga synvolcanic and syntectonic plutons (Hamner et al., 2000; Davis et al., 2000). To the northeast, the stratigraphy is dominated by volcanic rocks interbedded with clastic sedimentary rocks and banded iron formation, and semipelites interlayered with amphibolite (Hamner et al., in press, 2001). In the southwest, volcanic rocks include mafic pillowed to massive flows associated with gabbroic sills, volcanoclastic tuffs and breccia, and felsic tuffs (Hamner et al., 2000). In the south, immediately adjacent to the Nowyak complex, supracrustal rocks of the Kaminak Lake greenstone belt comprise a package of mixed volcanoclastic sediments, greywackes, schists, and gneisses (Relf et al., 1997).

The Kaminak greenstone belt is interpreted to represent a slice of Archean oceanic crust (Hamner et al., 2000), and may contain the remains of a calc-alkaline magmatic arc

(Hamner et al., 1998). It has minor chlorite alteration and quartz veins adjacent to the Hurwitz Group, but the majority of the greenstone belt has been interpreted to have escaped Paleoproterozoic reworking (Hamner et al., 1998). The belt records a relatively simple metamorphic history with no significant tectonic activity following the initial stabilization at 2.7 - 2.65 Ga (Davis et al., 2000).

Geochemically, the majority of the central Hearne domain records three distinct types of basaltic to andesitic volcanism: type 1 is characterized by flat incompatible element patterns lacking negative Nb and Ta anomalies, type 2 is Th and LREE-enriched with negative Nb, Ta, P, and Ti anomalies, and type 3 exhibit convex-upwards patterns culminating in La, Ta, P and Ti, with negative Ti and P anomalies (Sandeman, 2000). Sandeman (2000) suggested the central Hearne domain formed in an intraoceanic, island arc, and back-arc setting.

2.2.4 Hurwitz group

The Hurwitz Group, first mapped by Lord (1953), is distributed as a series of outliers within the Hearne province, and blankets an area of at least 140,000 km². It is composed of white quartzite with associated greywacke, conglomerate, impure quartzite, sedimentary schist, and carbonate rocks (Wright, 1955, 1967), and lies unconformably above Archean basement. The Hurwitz Group is unconformably overlain by the Kiyuk Group, a ca. 1.92 - 1.09 Ga a succession of conglomerate, arkose, and arkose-clast breccia (Aspler et al., 1989; Davis et al., 2000). Aspler and Chiarenzelli (1996) interpret the Hurwitz Group to represent a succession of Paleoproterozoic continental and marine deposits.

On the basis of lithostratigraphic units, the Hurwitz Group has been divided into four major sequences: Sequences 1 and 2 comprise the Lower Hurwitz Group; sequences 3 and 4 are referred to as the Upper Hurwitz Group. Sequence 1 consists of the Noomut, Padlei, and Kinga formations, and are composed of continental deposits which record initiation of the Hurwitz basin via post ca. 2.45 Ga regional intracratonic sagging and subsidence (Aspler and Chiarenzelli, 1997). Aspler and Chiarenzelli (in press, 2001) interpret this to be consistent with extension of a young, warm, orogenic lithosphere. Sequence 2, the Ameto formation, consists of texturally and compositional immature deep-water siliciclastic rocks, and is interpreted by Aspler and Chiarenzelli (in press, 2001) to have formed during a second period of renewed extension of continental lithosphere. Sequence 2 is overlain by a mixed siliciclastic-carbonate succession (sequences 3 and 4: Watterson, Ducker, and Tavani formations). Gabbro sill emplacement occurred after lithification of the Ameto Formation muds (Aspler and Chiarenzelli, in press, 2001) at ca. 2.11 Ga.

Hurwitz gabbro emplacement is separated from deposition of sequence 3 by a time gap of up to 200 Ma. The Hurwitz Basin was tectonically stable throughout this period, as indicated by the disconformable Watterson Formation - Whiterock Member contact (Aspler and Chiarenzelli, in press, 2001). Sequence 3 basin rejuvenation began with post ca. 1.91 Ga (youngest zircon = 1907 ± 27 Ma; Aspler, personal communication, 2001) deposition of the Watterson Formation on a "storm-dominated, microtidal, mixed siliclastic-carbonate ramp" (Aspler and Chiarenzelli, in press, 2001), and was overlain by prograde coastal and continental deposits of the Ducker and Tavani Formations (sequence

4). Aspler and Chiarenzelli (in press, 2001) interpreted the establishment of the continental-carbonate ramp as recording uplift along a basement-cored arch, basin-centered subsidence, and marine flooding. They suggested that it may have formed adjacent to a peripheral bulge of a foreland arc, or near an intracratonic arch. The rejuvenation of the Hurwitz Basin may have either been initiated during late extension within the central and northern Hearne domain, or to shortening related to early convergence in the western Trans-Hudson orogen (Aspler and Chiarenzelli, in press, 2001).

2.2.5 Proterozoic Granitoids

Between 1.85 and 1.75 Ga, there were two pulses of granitoid plutonism. Ca. 1.83 Hudsonian granitoids are dominantly monzonites, and postdate the majority of extensional fabrics and shear zones within the Hearne domain (Peterson et al., 2000). A P-T estimate from wallrock for one pluton near Chesterfield Inlet indicates emplacement at ca. 4 kbar (Berman et al., 2000). Peterson et al. (2000), on the basis of compositional and variation diagrams, suggested that the Hudson granitoid plutons were formed by emplacement of near-solidus, water-rich magmas into thin, partly concordant bodies at mid-crustal levels.

Ca. 1.75 Ga Nuelin granites are hypersolvus, with completely exsolved alkali feldspar phenocrysts (Peterson et al., 2000). Most are porphyritic, and most are associated with prominent negative gravity anomalies (Peterson et al., 2000). Geochemistry suggests that the Nuelin magmas were generated by intrusion of basalt into garnet-free crust, and either erupted as lavas or were emplaced as subvolcanic stocks

(Peterson et al., 2000). On the basis of Nd compositions, both the Hudsonian and the Nueltin granitoids are interpreted to have been derived from Archean crustal sources (Peterson et al., 2000), and may be related to lithospheric delamination. Emplacement of the plutons may have been the cause of the wide-spread ca. 1.8 to 1.7 Ga resetting observed throughout the Rae and Hearne provinces.

2.3 Regional Geology of the Nowyak Lake area

The moderately NW-dipping, NE-SW striking, Tyrrell shear zone represents one splay of the Snowbird tectonic zone near Yathkyed Lake (Figure 2-2; Map 1; Relf et al., 1999; MacLachlan, 2000). This shear zone separates two distinct tectonostratigraphic units, the Kaminak Lake greenstone belt and the Yathkyed greenstone belt. Overlying the contact between the Yathkyed Lake greenstone belt and the Kaminak greenstone belt are sedimentary rocks of the Hurwitz Group (Watterson formation; Aspler, 1996). Structurally, the Hurwitz Group lies above the Nowyak complex and provides an important constraint on the timing of tectonic loading (2.5, 1.9 or 1.83 Ga) related to high-pressure metamorphism in the area.

The Tyrrell shear zone appears to have a complex history with at least two episodes of movement. Early displacement along the Tyrrell shear zone involved oblique reverse displacement, and based on a syntectonic granitoid dyke, is interpreted to have occurred at ca. 2.62 Ga (Relf et al., 1999). Relf et al. (1999) suggest that this may represent a regional shortening event during which the Yathkyed Lake greenstone belt was thrust southeastward. Later oblique dextral-normal movement is Paleoproterozoic in age, as evidenced by a 1816 Ma mylonized granite dyke within the shear zone, and by a

1810 Ma granite dyke which cross-cuts the mylonites (MacLachlan et al., 2000). The Tyrrell shear zone projects along strike southwards towards the Nowyak shear zone and the Nowyak complex, the subject of this thesis.

The Nowyak complex was first mapped by Lord (1953) at a 1:506 880 scale, and later by Eade (1974, 1986) at 1:250 000 scale. Both broadly mapped the complex as a granitic pluton (Nowyak metagranite, recently dated at ca. 2.64 Ga; MacLachlan et al., in preparation, 2001) surrounded by volcanic and/or sedimentary rocks of Archean and/or Early Proterozoic age, but the Nowyak shear zone was not studied in detail until 1:50 000 mapping in 1997 (Relf et al., 1997). It is a shallow north-dipping zone of intense shear, deforming both the Hurwitz Group and mafic rocks correlated with the Yathkyed belt (Relf et al., 1997). The Nowyak shear zone experienced retrograde metamorphism from lower-amphibolite to greenschist facies, and the eastern limb records evidence for a later, post-tectonic amphibolite-facies overprint (Labelle, 1997).

Labelle (1997) documented top-to-the-north sense of displacement along the Nowyak shear zone, and suggested three possible genetic models: (1) a shear-fold model in which a planar shear zone was subsequently folded; (2) a metamorphic-core-complex model in which the curvilinear shear zone formed in a single extensional event; or (3) diapiric emplacement of the Nowyak metagranite pluton. A low-strain carbonate enclave, interpreted to be derived from the Hurwitz Group, led Relf et al. (1997) to conclude that motion on the Nowyak shear zone was Proterozoic in age. MacLachlan (2000) suggests that the Nowyak shear zone may be coeval and kinematically linked with the Tyrrell shear zone.

Relf et al. (1996; 1997) mapped the Nowyak complex as a broad, north-plunging antiform, exposing amphibolite grade Archean gneisses in the core. Within the 2.64 Ga granitic gneiss (MacLachlan, in preparation, 2001) are two high-grade supracrustal enclaves of garnet-kyanite-muscovite bearing pelite and garnet amphibolite. Preliminary data of Berman (unpublished data, 2000) suggested that a high-pressure metamorphic event at ~650 °C and 11.5 kbar.

Figure 2-1: Regional geology of the Western Churchill Province (WCP; modified from Wheeler et al., 1996). Star = location of Nowyok complex

Figure 2-2: Yathkyed Lake greenstone compilation map (modified from MacLachlan et al., 2000).

Yathkyed Lake Greenstone belt

Legend

Proterozoic

Hurwitz Gr.

Archean/Proterozoic

Post-tectonic granitoid

Higher TS Unit

Psammitic-pelitic schists

Mixed volcanic rocks

Tonalite

Lower TS Unit

"Komatik" granite

Mafic Volcanics

Carnecksluck
intrusive suite
(synvolcanic)

N
↑

20 km

Tyrrell Shear Zone

Mixed granitoid and
supracrustal rocks

Tyrrell Footwall

Mixed orthogneiss

Mixed supracrustal rocks

Calc-silicates

Syn-tectonic granitoids

Shear Zone

Synform

Antiform

Fault

Nowyak
Complex

Kaminak Lake
Greenstone belt

CHAPTER THREE: LITHOLOGY OF THE NOWYAK COMPLEX

FIGURES:

Figure 3-1: Geologic map of the Nowyak complex

PLATES:

- Plate 3-1: Representative field photograph of two-mica metagranite**
- Plate 3-2: Moderately deformed metagranite**
- Plate 3-3: Representative field photograph of Stonecutter supracrustal unit**
- Plate 3-4: Garnet amphibolite gneiss**
- Plate 3-5: Plagioclase decompression rims**
- Plate 3-6: Garnet kyanite pelitic schist**
- Plate 3-7: Representative field photograph of chlorite schist**
- Plate 3-8: Porphyroblasts of plagioclase within chlorite schist**
- Plate 3-9: Small internal boudin within chlorite schist**
- Plate 3-10: Hornblende rosettes overgrowing a chlorite schistosity in amphibolite**
- Plate 3-11: Hornblende lineation within amphibolite**
- Plate 3-12: Dolomitic marble**

TABLES:

Table 3-1: Summary of lithologies and mineralogy of Nowyak complex map area

CHAPTER THREE: LITHOLOGY OF THE NOWYAK COMPLEX

3.1 Introduction

Rocks in the vicinity of the Nowyak complex (Map 1 and 2; back pocket, Figure 3-1; Table 3-1a, b, c) can be separated into three domains: hanging wall, shear zone, and footwall rocks, with respect to the Nowyak shear zone. The Nowyak complex includes footwall rocks and rocks from the Nowyak shear zone. Hanging wall rocks include mafic to intermediate volcanoclastic metasedimentary rocks of the Yathkyed Lake and Kaminak Lake greenstone belts, and Hurwitz Group sedimentary rocks. The Nowyak shear zone consists of chlorite schist, with small lenses of amphibolite. The footwall consists of a two-mica metagranite, with several enclaves of pelitic schist and garnet amphibolite. Henceforth, these enclaves will be referred to as the Stonecutter supracrustal unit.

3.2 Lithology of hanging wall rocks

3.2.1 *Yathkyed Lake greenstone belt*

The Yathkyed Lake greenstone belt (Map 2; back pocket, Figure 3-1) is dominated by mafic volcanic rocks with a smaller component of felsic metavolcanic rocks, metagreywackes, and high-grade metasediments. The volcanic rocks can be subdivided into two units (Relf et al., 1997), one characterized by pillowed and massive flows, and the other composed mainly of mafic to intermediate volcanoclastic material. Mafic pillowed and massive flows contain plagioclase phenocrysts and/or quartz-filled amygdules, and in places, the mafic flows are interbedded with volcanoclastic rocks. Metasedimentary rocks include psammites and semi-pelites to pelites, and Relf et al. (1998) interpret graded bedding and local crossbeds to indicate younging towards the

southeast. Locally chlorite-rich crossbeds and the presence of euhedral to subhedral plagioclase clasts suggest detritus from a volcanic source (Relf et al., 1998).

Relf (1996) mapped a hornblende-in isograd approximately 50 km north of the Nowyak complex. Typical mineral assemblages north of the hornblende-in isograd include hornblende + garnet, hornblende + garnet + epidote (Relf et al., 1998). South of the isograd, typical mineral assemblages contain plagioclase + quartz + actinolite, with a minor component of hornblende, epidote, and chlorite. This likely reflects a transition from amphibole to greenschist facies.

The Yathkyed belt hosts three cross-cutting plutonic suites: the Carnecksluck intrusive suite, a post Carnecksluck-suite granite, and the "yellow" granite. The Carnecksluck batholith is heterogeneous, and includes biotite tonalite, gabbro, leucogabbro to anorthosite, diorite, and granodiorite. Gabbro sills, dykes, and stocks are spatially associated with the mafic volcanic rocks, and are textually and mineralogically similar to those of the Carnecksluck intrusive suite, leading Relf et al. to suggest that parts of the intrusive suite may be synvolcanic. The post-Carnecksluck suite is characterized by massive, medium grained to pegmatitic biotite monzogranite, and intrudes both the greenstone belt and the Carnecksluck intrusive suite. The "yellow" granite is massive to fine grained, and occurs as three small, isolated plutons near the west end of the Carnecksluck batholith. It is commonly rusty on the weathered surface, and locally contains up to 80% sulphide minerals (Relf et al., 1997).

3.2.2 Kaminak Lake greenstone belt

In general, the Kaminak Lake greenstone belt consists of a well exposed, east-northeast trending corridor of predominantly volcanic rocks, flanked on either side by poorly exposed metasedimentary rocks (Hanmer et al., in preparation, 2001). The central core is primary composed of intermediate volcanoclastic material, felsic to mafic flows, volcanic breccia, and diorite, which are surrounded in the north, east, and south by mafic, pillowed to massive flows and layered mafic rocks (Hanmer et al., in preparation, 2001). Felsic rocks, interpreted by Davis et al. (in press, 2001) to be deposited in a volcanic succession, are contemporaneous with tonalite-granodiorite plutons (Hanmer et al., in preparation, 2001). In the south, greenschist-facies metasedimentary rocks are primarily composed of fine-grained arenite, and include a volcanoclastic component and extensively developed iron formations. In the north, amphibolite-facies metasedimentary rocks include homogeneous semi-pelitic and amphibolitic gneiss, which have been intruded by granitoid plutons (Hanmer et al., in preparation, 2001).

Near the Nowyak complex, the Kaminak Lake greenstone belt consists predominantly of volcanic and volcanoclastic sedimentary rocks of mafic to intermediate composition, and locally contains magnetite on the bedding surfaces. In places, up to 50% of the rock is defined by angular to rounded clasts of mafic to felsic volcanic material. Greywacke is mapped in the southwestern part of the Kaminak belt, and consists of sandy and muddy beds interbedded at a 1 to 10 cm scale (Relf, 1996; Relf et al., 1997).

3.2.3 Hurwitz Group

Near the Nowyak complex, Hurwitz group rocks are represented by the Kinga and the Watterson formations, and consist of quartz arenite, dolostone, and arkose to shale (Map 2; back pocket, Figure 3.1). The quartz arenite (> 75% quartz) is thickly bedded (0.5 - 2 metres), and is characterized by its white colour and the presence of ripple marks. It is quartz-rich sandstone varying from predominantly coarse quartz grains to coarse quartz grains containing sand-sized lithic fragments. It is overlain by dolomite, which is thinly laminated (1 - 5 mm), and weathers to distinctive buff to brown colour. Overlying the dolomite is light grey to buff arkose (Relf et al., 1997).

3.3 Lithology of footwall rocks

3.3.1 Biotite-muscovite schist

Biotite-muscovite schist occurs immediately south of the Nowyak shear zone, on the western side of the Nowyak complex (Map 2; back pocket, Figure 3.1). The schist is medium grained, and is characterized by a rusty red-brown weathered surface. The main mineral assemblage includes biotite, quartz, plagioclase feldspar. Other minerals present include muscovite and chlorite.

3.3.2 Metagranite

A variably deformed, ca. 2.64 Ga (MacLachlan et al., in preparation, 2001) two-mica metagranite is exposed in the core of the Nowyak antiform (Map 2; back pocket, Figure 3-1). The metagranite is resistant to weathering, and forms a large outcrop several kilometres in diameter. The pluton is medium to coarse grained, and is a pale pink colour on both the weathered and the fresh surface (Plate 3-1). The typical mineral assemblage

includes quartz, biotite, and potassium feldspar. Other minerals include epidote, chlorite, muscovite, plagioclase, and ilmenite (Plate 3-2).

3.3.3 Stonecutter supracrustal unit

Supracrustal rocks are exposed as two large enclaves within the core of the metagranite pluton (Map 2; back pocket, Figure 3-1). Though outcrop is sporadic and not well exposed in this area, the enclaves may be up to 5 kilometres in length and 2 kilometers in width. Contacts are not exposed, and it is unclear from field relationships whether these enclaves are tectonic slices, rafts hosted within the pluton, or sedimentary outliers. They consist of psammite, semi-pelite, and pelite schist interlayered at a scale of metres to tens of metres with amphibolite, garnet amphibolite, and gneissic amphibolite (Plate 3-3). Contacts between pelite schist and gneissic amphibolite were not observed.

Gneissic amphibolite

Medium-grained amphibolite, garnet amphibolite, and gneissic amphibolite are interlayered at a scale of metres to tens of metres (Plate 3-4). The weathered surface is a pale to medium grey colour, with plagioclase weathering chalky white. Mineral assemblages include hornblende, plagioclase, garnet, and quartz. Garnet porphyroblasts range in size from 0.1 to 1.5 cm, and some show coronas of plagioclase (Plate 3-5). Amphibolite gneiss contains alternating felsic and mafic bands at millimetre to centimetre scale.

Metasedimentary rocks

Metasedimentary rocks are compositionally variable, and include psammite, semi-pelite, and pelite interlayered at a scale of metres to tens of metres. Psammite, consisting

of quartz, biotite, and plagioclase, occurs predominantly in the western portion of the Stonecutter supracrustal enclave as large areas of heaved rock. It is a fine to medium-grained rock which weathers a spotty-grey colour on the exposed surface, and on the fresh surface is a distinctive "salt and pepper" colour.

Garnet-kyanite pelitic rocks are medium to coarse grained, weather a rusty red colour (Plate 3-6), and contain biotite, quartz, muscovite, garnet, plagioclase, and kyanite. Garnet porphyroblasts range from 1 to 1.5 cm in diameter, whereas kyanite porphyroblasts are 0.5 to 1 cm in length. Some garnet and kyanite porphyroblasts are fractured, and garnet is often rimmed by a fine-grained, randomly-oriented mixture of plagioclase, quartz, muscovite, biotite, and chlorite.

3.4 Lithology of the Nowyak shear zone

3.4.1 *Chlorite schist*

Chlorite schist is very fine grained, and is a pale green-grey colour on both the weathered and fresh surface (Map 2; back pocket, Figure 3-1). It is well exposed along Nowyak Lake, where it is visible on two small islands, and locally forms ridges and cliffs (Plate 3-7). Typical mineral assemblages include chlorite, quartz, and plagioclase. Other minerals include actinolite, hornblende, calcite, pyrite, and ilmenite, though the relative proportions of actinolite and hornblende vary across section and along strike. Relict primary compositional layering may be locally preserved as <1 cm thick hornblende and actinolite rich layers (or this could represent a retrograde hornblende to actinolite reaction). Quartz and calcite occur locally as boudinaged veins measuring <25 cm in length, and as small rotated porphyroclasts (Plate 3-8). Small internal boudins are also

recorded within the chlorite schist (Plate 3-9). Retrograde minerals include epidote, apatite, and sericite.

Contacts between chlorite schist and amphibolite enclaves are gradational on the scale of metres. Chlorite schist contains scattered relict hornblende grains (see Chapter 4). Some hornblende crystals are folded and fractured, and in places, chlorite grows within the fractures and along cleavage planes, indicating retrogression to greenschist grade during deformation. Amphibolite enclaves found within the chlorite schist may represent the low-strain, higher-grade equivalent of the chlorite schist.

3.4.2 Enclaves within the shear zone

Amphibolite enclaves range from fine to medium grained, and are a dark grey-black colour on both the weathered and fresh surface. The enclaves range in size from approximately 10 metres to 120 metres in length, and 10 to 50 metres in width, and occur throughout the Nowyak shear zone (Map 2; back pocket, Figure 3.1). Typical mineral assemblages include hornblende, actinolite, chlorite, quartz, and plagioclase. Other minerals include potassium feldspar, calcite, biotite, and ilmenite. In places, hornblende rosettes cross cut the chlorite-bearing schistosity (Plates 3-10, 3-11).

One granite enclave, measuring approximately a meter in length, was observed within the Nowyak shear zone. The medium-grained granite is pale pink on both the fresh and weathered surface, and the mineral assemblage includes quartz, plagioclase, potassium feldspar, biotite $\pm$ muscovite. This granite enclave could be related to the Carnecksluck intrusive suite found to the north (hanging wall rock), or to the pluton found immediately to the south (within the footwall; see above).

Two small enclaves of dolomite (Plate 3-12) occur within the western part of the Nowyak shear zone. The dolomite enclave weathers a pale brown buff, and is pale grey-white with fine laminations on the fresh surface. These enclaves have tentatively been correlated with rocks of the Watterson Formation (Relf et al., 1997), suggesting an upper time limit of deformation along the Nowyak shear zone to be ca. 1907 ± 27 Ma (Aspler and Chiarenzelli, in press, 2000).

Figure 3-1: Simplified geology of the Nowyak Lake area, modified from Relf et al., 1996.

Plate 3-1: Representative field photograph of metagranite (Nowyak footwall). Rocks strike NW-SE and dip gently to the NE. Photograph is ~ 4 metres across.

Plate 3-2: Moderately deformed metagranite (Nowyak footwall). Rock is cut perpendicular to foliation and parallel to lineation

Plate 3-3: Representative field photograph of garnet amphibolite, Stonecutter supracrustal unit. Rocks strike NW-SE, and dip gently to the NE.

Plate 3-4: Garnet amphibolite gneiss, with alternating quartzofeldspathic and hornblende rich layers.

Plate 3-5: Garnet amphibolite. Garnet is rimmed by plagioclase.

Plate 3-6: Garnet-kyanite-pelitic schist intruded by large quartz vein. Rock is cut parallel to the foliation and perpendicular to the lineation.

Plate 3-7: Westward view of representative field photograph of chlorite schist in the hanging wall of the Nowyak shear zone. Rocks strike ~ E-W and dip to the north. Hammer is 30 cm.

Plate 3-8: Chlorite schist of the Nowyak shear zone, with large porphyroclasts of plagioclase. Rock is cut parallel to lineation and perpendicular to the foliation.

Plate 3-9: Small internal boudin within chlorite schist of the Nowyak shear zone, containing alternating layers of felsic (plagioclase and quartz) and mafic (hornblende and actinolite) layers. Rock is cut parallel to the lineation and perpendicular to the foliation.

Plate 3-10: Bow-tie rosettes of hornblende within amphibolite enclave of the Nowyak shear zone. Rock is cut parallel to the lineation and perpendicular to the foliation.

Hornblende rosettes

Plate 3-11: Strong hornblende lineation on foliation from an amphibolite enclave of the Nowyak shear zone. Canadian dollar for scale.

Plate 3-12: Folded dolomitic marble from enclave within the Nowyak shear zone. Penny for scale.

3-11

Table 3-1a: Nowyok wallrock: units, lithologic characteristics, and possible protoliths (modified from Relf et al., 1997).

Map Unit	Subunit	Lithology	Unit Description	Possible Protoliths
Hurwitz Group	Arkose phyllite	Arkose phyllite	- light grey to buff colour	N/A
Hurwitz Group	Dolomite	Dolomite	- weathers a distinctive buff to brown colour - thinly laminated at a scale of 1 - 5 mm.	Carbonate
Yathkyed Lake greenstone belt	"yellow" granite	Granite	- contains up to 80% sulphide minerals	N/A
Yathkyed Lake greenstone belt	post-Carnecksluck granite	Biotite muscovite monzogranite	- medium grained to pegmatitic	N/A
Yathkyed Lake greenstone belt	Carnecksluck intrusive suite	Biotite $\pm$ chlorite tonalite, gabbro, leucogabbro to anorthosite, diorite, granodiorite	- medium grained	N/A
Yathkyed Lake greenstone belt	Metasedimentary rocks	Psammite Semi-pelite	- graded bedding and crossbeds indicate southeastward younging - locally, chlorite-rich beds and euheral to subheral plagioclase clasts suggest detritus from a volcanic source	Sedimentary or volcanic rocks
Yathkyed Lake greenstone belt	Volcanic rocks	Amphibolite Chlorite schist	- pillowed and massive flows - locally characterized by plagioclase phenocrysts and/or quartz-filled amygdulites	Volcanic rock

Table 3-1a (continued): Nowyok wallrock: units, lithologic characteristics, and possible protoliths (modified from Relf et al., 1997).

Map Unit	Subunit	Lithology	Unit Description	Possible Protoliths
Kaminak Lake greenstone belt	Volcaniclastic rocks	Chlorite schist Amphibolite	<ul style="list-style-type: none"> - contains magnetite on bedding surfaces - locally, up to 50% of the rock is clasts of mafic and felsic volcanic material - sandy and muddy beds are interbedded at a 1 to 10 cm scale 	Volcanic rock

Table 3-1b: Nowyok shear zone: units, lithological characteristics, and possible protoliths.

Map Unit	Lithology	Unit Description	Model Mineralogy	Possible Protoliths
Chlorite schist	Chlorite actinolite $\pm$ hornblende schist	<ul style="list-style-type: none"> - very fine grained - pale green colour on both the weathered and the fresh surface - mm-scale compositional layering defined by actinolite and hornblende rich layers 	45% chlorite 25% quartz 15% actinolite/hornblende 10% plagioclase 5% opaques	Mafic volcaniclastic sediments
Amphibolite	Amphibolite	<ul style="list-style-type: none"> - fine to medium grained - dark grey black colour on both the weathered and the fresh surface - in places, hornblende rosettes have overgrown chlorite-bearing schistosity 	40% hornblende 30% quartz 20% chlorite 5% calcite 5% opaques	Mafic volcaniclastic sediments

Table 3-1c: Nowyack footwall: units, lithological characteristics, and possible protoliths.

Map Unit	Lithology	Unit Description	Model Mineralogy	Possible Protoliths
Biotite muscovite schist	Biotite muscovite schist	- medium grained - rusty red-brown weathered surface - homogenous	40% quartz 25% muscovite 20% biotite 15% plagioclase	Mud and/or siliciclastic sediments
Metagranite	Muscovite biotite metagranite	- medium to coarse grained - pale pink colour on both the weathered and the fresh surfaces	55% quartz 20% microcline 15% biotite 5% plagioclase 5% muscovite	Granite
Amphibolite	Amphibolite	- medium grained - weathers to a pale to medium grey colour -schistose	50% hornblende 30% plagioclase 15% quartz 5% biotite	Mafic volcanoclastic sediments
	Garnet amphibolite	- medium grained - 1 - 15 mm garnet porphyroblasts overgrow hornblende schistosity, and locally show moats of plagioclase	50% hornblende 20% plagioclase 20% quartz 5% garnet 5% biotite	Mafic volcanoclastic sediments
	Gneissic amphibolite	- alternating mafic and felsic bands at a mm scale	50% hornblende 30% plagioclase 15% quartz 5% biotite	Mafic volcanoclastic sediments

Table 3-1c (continued): Nowyak footwall: units, lithological characteristics, and possible protoliths.

Map Unit	Lithology	Unit Description	Model Mineralogy	Possible Protoliths
Metasedimentary rocks	Biotite psammite	<ul style="list-style-type: none"> - medium grained - weathers a spotty-grey on the exposed surface, with a distinctive "salt & pepper" colour on the fresh surface 	60% quartz 30% biotite 10% plagioclase	Mud and/or siliciclastic sediments
	Kyanite-garnet-muscovite-biotite schist	<ul style="list-style-type: none"> - medium to coarse grained - weathers to a rusty red colour - 1 to 1.5 cm garnet porphyroblasts syntectonic to mica schistosity 	30% quartz 30% biotite 15% muscovite 10% plagioclase 10% garnet 5% kyanite	Mud and/or siliciclastic sediments

CHAPTER FOUR: STRUCTURE OF THE NOWYAK COMPLEX

FIGURES:

Figure 4-1: Simplified geology of the Nowyak Lake area (after Relf et al., 1996)

Figure 4-2: Stereonet projections (S_m) for Nowyak footwall rocks

Figure 4-3: Stereonet projections for mineral and extensional lineations within the
Nowyak shear zone

Figure 4-4: Stereonet projections (S_{my}) for the Nowyak shear zone

Figure 4-5: Stereonet projections and interpretation for the Nowyak complex

PLATES:

Plate 4-1: Post S_m shallowly-north plunging fold

Plate 4-2: Isoclinal to tight post S_{my} fold

Plate 4-3, 4: Rootless, pre- S_{my} isoclinal fold

Plate 4-5, 6, 7: Asymmetrical, left-lateral, extensional shear bands

Plate 4-8, 9, 10, 11: Relict porphyroclasts consistent with a top-to-the-north sense of
motion

Plate 4-12, 13: Strain gradient between footwall, hanging wall, and shear zone rocks

Plate 4-14, 15, 16: SEM images of annealed quartzo-feldspathic matrix (Nowyak shear
zone)

Plate 4-17: Relict strained fabric preserved within layers of a predominantly annealed
chlorite mylonite (Nowyak shear zone)

Plate 4-18: Coarse-grained hornblende overprints chlorite matrix (Nowyak shear zone)

CHAPTER FOUR : STRUCTURE OF THE NOWYAK COMPLEX

4.1 Introduction

Lord (1953), mapping at a scale of 1:506 880 in the southern District of Keewatin, first described the Nowyak complex as a granitic pluton surrounded by Archean and/or Proterozoic volcanic and/or sedimentary rocks. Detailed mapping (1: 50 000) by Relf et al. (1996) recognized the Nowyak shear zone, a shallow, north-dipping zone of intense shear. Structural analysis of the Nowyak shear zone was undertaken for a B.Sc. honours thesis by Labelle (1997), who suggested three possible genetic models for the complex: a shear-fold model in which the shear zone was formed in a planar fashion and subsequently folded, a metamorphic core complex model in which the curvilinear shear zone formed in a single extensional event; or a diapiric-pluton model in which emplacement of a pluton at the core of an antiform would create a curved foliation, down-dip lineations, and opposing kinematic indicators along the Nowyak shear zone.

This chapter addresses first-order structural observations regarding the Nowyak complex; further discussion of deformation with respect to the timing of metamorphism is considered in Chapter 6. For comparative purposes, the structure and geometry of the Nowyak complex and surrounding rocks are discussed in terms of the hanging wall, footwall, and the Nowyak shear zone. All structural terminology used is from Twiss and Moores (1992).

4.2 Hanging wall rocks

The hanging wall includes rocks of the Yathkyed and Kaminak Lake greenstone belts, and Hurwitz Group sedimentary rocks (Chapter 2; Figure 4-1). The Yathkyed Lake

greenstone belt is structurally divided into three tectonostratigraphic units (Figure 2-3).

Two units sit within the hanging wall of the Tyrrell shear zone, and are referred to as the higher and lower tectonostratigraphic units, respectively (Chapter 2). The third unit includes rocks in the footwall of the Tyrrell shear zone (Relf et al., 1999). The Yathkyed Lake belt dips moderately to the northwest. Pillows within felsic volcanic rocks indicate younging towards the southeast, leading Relf et al. (1998) to suggest that it may represent an overturned panel.

The predominant foliation within the Yathkyed Lake greenstone belt, S_{main} , is defined by alignment of metamorphic minerals, is generally parallel to bedding, and ranges from southwest-striking in the west to west-striking in the east (Relf et al., 1998; 1999). Relf et al. (1998) note that down grade (south) from the hornblende isograd (Chapter 6), two foliations are locally preserved in hinge zones of open to tight Z-asymmetric folds (F_3). S_{main1} , interpreted by Relf et al. (1998) to be the equivalent of S_{main} , is defined by a layer-parallel penetrative fabric, and is overprinted by a northwest-dipping cleavage (S_{main2}). Upright to steeply overturned F_2 folds strike east to northeast, and are doubly plunging as a result of northeast-striking F_3 folds (Relf et al, 1999). F_3 folds plunge shallowly to moderately northeast, and deform bedding, S_1 , and the hornblende isograd (Relf et al., 1998).

Kaminak Lake volcanoclastic rocks contain a bedding-parallel foliation, defined by the orientation of metamorphic minerals, that is similar to S_{main} documented in the Yathkyed Lake greenstone belt (Relf et al., 1997). Relf et al. (1997) also called this foliation S_{main} , but note that it is unclear whether S_{main} in the Kaminak belt is correlative

with S_{main} in the Yathkyed belt. Both bedding and S_{main} are deformed into upright, gently south-plunging, open folds with wavelengths in the order of metres to tens of metres. Associated with the folding are strong mineral and stretching lineations, defined by the alignment of hornblende and elongation of clasts, respectively. Lineations parallel the south-plunging fold axis, whose axial surfaces also parallel those of F_3 folds in the Yathkyed Lake greenstone belt (Relf et al., 1997).

The Hurwitz Group overlies the contact between the Yathkyed Lake and Kaminak Lake greenstone belts. It preserves a moderately-to-steeply dipping, northeast-striking, bedding-parallel foliation (phyllitic cleavage) that is similar in orientation to S_{main} in the underlying Yathkyed Lake and Kaminak Lake greenstone belts (Relf et al., 1997). Hurwitz Group rocks preserve two sets of folds. Relf et al. (1997) interpreted locally overturned bedding to represent the overturned limb of a recumbent F_1 fold. Open, shallowly north-plunging folds deform the bedding and cleavage, have wavelengths on the order of several kilometres (Relf et al., 1997), and are parallel to the F_3 crossfolds mapped in the Yathkyed Lake greenstone belt (Relf et al., 1999).

4.3 Footwall rocks

As it is unclear whether the S_{main} foliation observed by Relf et al. (1996, 1997) is the equivalent to foliations within the Nowyak footwall, a different terminology (S_m) is applied to these rocks. Although S has different designations (i.e. it is based on either a compositional or disjunctive foliation) in each domain, S_m always delineates the main foliation. Correlations between S_m within individual domains are uncertain.

4.3.1 Biotite-muscovite schist

A thin lens of biotite-muscovite schist occurs immediately adjacent to the Nowyak shear zone (Chapter 3). Biotite-muscovite schist generally strikes $\sim 250^\circ$ SW, and dips moderately towards the NW. S_m within this lens is defined by an anastomosing to rough disjunctive foliation, and consists of wavy cleavage domains (1 - 5 cm apart) defined by discontinuous concentrations of biotite and muscovite. Microlithons exhibit weakly oriented fabrics defined by recrystallized quartz and plagioclase crystals.

4.3.2 Nowyak metagranite

Foliation varies in intensity in the Nowyak metagranite, and ranges from a diffuse foliated granite to banded gneiss (S_m), and is classified as a $S>L$ tectonite, though MacLachlan (in prep.) locally notes a strong L-S fabric. The spatial pattern of foliation variations is not known, though the orientation of the foliation varies systematically in orientation from west to east; in the NW the foliation strikes $\sim 250^\circ$ and dips moderately to the NW, whereas in the NE, the foliation strikes $\sim 340^\circ$ and dips moderately to the NE (Map 1; back pocket; Figure 4-1; 4-2). The banded compositional foliation within granitic gneiss is characterized by closely spaced (<1 cm) mafic and felsic compositional layers, containing elongate aggregates of biotite, plagioclase and quartz. Less strained metagranite displays a weak to moderate diffuse compositional foliation, characterized by widely spaced (>1 cm), weak concentrations of biotite, and elongate aggregates of plagioclase and quartz.

4.3.3 Stonecutter supracrustal unit

The foliation within the Stonecutter supracrustal unit strikes $\sim 280^\circ$, and dips moderately to the N (Figure 4-1; 4-2). Within psammitic and pelitic schist, S_m is generally an anastomosing to rough disjunctive foliation, defined by short, discontinuous domains of preferentially oriented biotite, muscovite and kyanite, and elongate aggregates of plagioclase and quartz. Compositional variations of phyllosilicate-rich layers and biotite-rich seams form layers that have been transposed into parallelism with S_m . Garnet amphibolite and garnet amphibolite gneisses display both a rough disjunctive foliation and a banded compositional foliation, respectively. Within the garnet amphibolite, the moderate to strong disjunctive foliation is defined by discontinuous concentrations of hornblende and biotite, and microlithons display a weak to strong preferred orientation of quartzo-feldspathic aggregates. Banded compositional foliations within garnet amphibolite gneiss are characterized by closely spaced ($> 1\text{cm}$) mafic (hornblende and biotite) and felsic (quartz and plagioclase) compositional layers.

4.3.4 Structures associated with S_m

Mineral and extensional lineations. Footwall rocks consistently contain a shallow north-plunging mineral lineation, defined by elongate biotite, kyanite, and hornblende grains. Close to the Nowyak shear zone, metagranitic mylonite preserves an extensional lineation defined by elongate aggregates of plagioclase and quartz ribbons (see section 4.4 for a detailed kinematic analysis of the shear zone and extensional lineations within it). The average orientation of lineations within the footwall is $23^\circ/340^\circ$ (Figure 4-2).

Folds. Within the Stonecutter supracrustal unit, open to tight F_{m+1} folds plunge shallowly north-to-northeast, and fold S_m (Plate 4-1). They are upright elliptical folds with amplitudes ranging from 1 to 2 metres; fold axes are generally collinear with mineral lineations. Relf et al. (1996) mapped similar folds within the metagranite. A map-scale fold similar in orientation to F_{m+1} outcrop-scale folds is apparent from stereonet projections (see section 4.5).

4.4 Nowyak shear zone

The dominant fabric in Nowyak shear zone is defined by a coarse-continuous to rough-disjunctive foliation, interpreted as a shear foliation. The moderately north-dipping curvilinear shear zone strikes SW-NE in the west, and NW-SE in the east (Figure 4-3). Moderately dipping C-planes, which define S_{my} ($S_{mylonite}$) within the shear zone, are concordant to S_m within the footwall and form part of a Type I S-C fabric (Twiss and Moores, 1992). A northwest- to north-trending, shallowly plunging extensional lineation ($24^\circ/345^\circ$), is defined by quartz ribbons and elongate plagioclase aggregates. Collinear to the extensional lineation is a mineral lineation ($24^\circ/341^\circ$), defined by elongate hornblende and actinolite grains, and is best seen within low-strain amphibolite enclaves.

S-planes occur as cm- to micro-scale discontinuous zones of very fine grained, preferentially oriented plagioclase and hornblende aggregates and quartz ribbons. C-planes occur as penetrative shear planes and are defined by elongate hornblende, chlorite, and plagioclase aggregates. S-planes are oriented at an angle of 45 degrees or less to the

C-plane; they form at 45° to the shear plane and rotate into the shear plane with progressive strain (Hanmer and Passchier, 1991).

Low-strain enclaves of amphibolite are preserved within the greenschist-facies shear zone, both of which contain the main shear foliation (Figure 4-4). S_0 , original bedding, may be preserved locally by centimetre-scale hornblende and actinolite layers and/or opaque minerals that have been transposed into S_{my} . A mineral lineation ($21^\circ/345^\circ$), defined by elongate hornblende and actinolite grains, is similar in style and orientation to that observed within the chlorite schist. Relf et al. (1996) note a S_{my+1} foliation, locally preserved as a penetrative crenulation cleavage, which lies parallel to the main lineation ($\sim 20^\circ/345^\circ$). It may be related to either the late-stage shearing or a post-shear folding event.

The west side of the Nowyak shear zone is truncated by a narrow, steeply northwest-dipping, northeast-striking brittle fault. No movement direction could be determined from the fault breccia (Relf et al., 1997).

4.4.1 Structures associated with S_{my}

Mineral and extensional lineations. Colinear mineral and extension lineations are common throughout the shear zone. Mineral lineations are defined by elongate hornblende and/or actinolite grains, and are best observed within amphibolite enclaves. Chlorite schist sometimes contains a less well-developed mineral lineation defined by fine-grained hornblende crystals. Mineral lineations plunge shallowly to the northwest, with an average orientation of $21^\circ/343$ NW (Figure 4-4).

Extension lineations, or stretching lineations, are defined by elongate aggregates of recrystallized quartz and plagioclase. They are observed predominantly within the chlorite schist, and plunge shallowly to the northwest with an average orientation of 24°/345 NW (Figure 4-4).

Folds. Rare F_{my} folds (Plate 4-3; 4-4) are observed as intrafolial rootless isoclinal folds, and attenuated fold limbs lie coplanar with S_{my} . Preserved within S_{my} are small, cm-scale, cylindrical F_{my+1} folds (Plate 4-2), with wavelengths in the order of 10 to 20 cm and amplitudes of 5 to 10 cm. F_{my+1} folds are tight to isoclinal, and fold the S_{my} foliation. Fold axes plunge shallowly to moderately to the north at 20° - 35°. Folds contain a penetrative axial planar cleavage which parallels S_{my} , and are generally collinear with mineral and stretching lineations throughout the area.

4.4.2 Kinematic and shear sense indicators

Kinematic indicators are structures which may allow a determination of sense of motion (for simple shear), or sense of flow, recorded within a shear zone during progressive deformation. Within a shear zone the S-plane will form at 45° to the shear plane, rotate towards the shear plane with progressive deformation, and will record the sense of rotation of the finite strain ellipsoid with respect to the instantaneous stretching axes (Hamner and Passchier, 1991). In the case of progressive simple shear, valid shear sense indicators will be recorded within the plane that contains both the maximum and the minimum axes of the strain ellipsoid. This is in the section of rock that is oriented perpendicular to the dominant foliation, and parallel to the dominant extension lineation.

Asymmetrical extensional shear bands

Shear bands are discontinuous zones of concentrated shear, oriented at about 15° - 25° to the flow plane, which form in anisotropic rocks subjected to homogeneous flow parallel to the plane of anisotropy. In general, they may be up to several millimetres thick and 10 centimetres long, and can either be penetratively (i.e. constitute a foliation or crenulation cleavage) or sporadically developed. Shear bands may either be composed of the same mineralogy as the rest of the rock, show compositional changes (i.e. retrograde metamorphism), or have a concentration of less soluble material (Hamner and Passchier, 1991).

Slip on extensional shear bands results from a component of extension within the flow plane. In cases where there is only one set of shear bands preferentially developed, a dextral shear band records a clockwise sense of motion, whereas sinistral shear band records an anti-clockwise sense of motion.

In the western portion of the Nowyak shear zone, the shear foliation is northeast striking and records a shallowly north-northwest plunging extension lineation. Numerous thin-section-scale shear bands are preserved displaying consistent sinistral shear sense kinematics, indicating top-to-the-north sense of motion (Plate 4-5 - 4-7). Labelle (1997) documents a similar top-to-the-north sense of shear from asymmetrical extensional shear bands located in the eastern portion of the shear zone.

C-S fabrics

A C-S fabric is a strain-sensitive fabric that consists of two planar features: *Cisaillement* (C or shear) planes are discrete narrow shear zones which lie parallel to the

flow plane of the progressive deformation; *Schistosity* (S foliation) planes represent penetratively developed strain-sensitive flattening fabrics which track the XY plane of the finite strain ellipsoid during progressive deformation (Hanmer and Passchier, 1991). C-S fabrics are created when the S foliation, formed initially at 45 degrees to the shear plane, rotates towards parallelism with the shear plane during progressive deformation (Ramsay and Graham, 1970; Hanmer and Passchier, 1991). The long axis of elongate and pulled-apart minerals lie within the maximum extension direction contained within the flattening plane. The orientation of the S-plane with respect to the C-plane displays the direction of rotation, and thus shear sense.

Outcrop 121 preserves well-developed C-S fabrics. The S-fabric is defined by elongate aggregates of hornblende and plagioclase. The C-fabric is defined by discrete zones of high shear strain, characterized by recrystallized quartz ribbons, ranging from centimetre to 10's of centimetres in length. The orientation of the S-plane with respect to the C-plane indicates a clockwise sense of shear, which is equivalent to a top-to-the-north sense of motion.

Mantled porphyroclasts, winged inclusions, and pressure shadows

A mantled porphyroclast has a high density of subgrains around its margins. In response to strain, the rim of a porphyroclast develops subgrains which subsequently may be deformed into wings extending on both sides of the porphyroclast, paralleling the shape fabric in the rock (Passchier and Trouw, 1996). Matrix grains nearby the porphyroclast, oriented between 3 - 10° to the main foliation, may parallel the orientation of subgrains. Wings will stretch and change shape while the porphyroclast core remains

rigid or continues to recrystallize in the rim, resulting in a stair-step geometry. Initially, the wings will be parallel to each other and to the shear plane, but will not lie within the same plane. With progressive deformation, the stair-step geometry will alter to in-plane geometry in which the two wings lie in the same plane (Hamner and Passchier, 1991).

Within the motion plane, five different types of mantled porphyroclasts have been identified: θ -type objects lack wings, ϕ -type objects have a mantle with orthorhombic symmetry, and σ -type, δ -type and complex objects (several pairs of wings) have monoclinic symmetry (Passchier and Trouw, 1996). A σ -type geometry occurs when wings stream parallel to the shear plane, while a δ -type geometry will occur when wings cross the shear plane in the area adjacent to the inclusion. The stair-stepping of wings within σ -type, δ -type, and complex objects may be used as a shear sense indicator, as wings will step up in the direction of movement. A mantled porphyroclast with an upper wing to the left of its associated inclusion indicates an anti-clockwise sense of shear, while an upper wing located to the right of the inclusion will indicate a clockwise sense of shear (Hamner and Passchier, 1991).

Pressure shadows are polycrystalline aggregates, without an internal shape fabric, which lie adjacent to stiff crystals, porphyroblasts, or aggregates. As progressive deformation occurs, the matrix extends faster than does the stiff inclusion. This results in a zone of anomalously low pressure in the pressure shadow of the porphyroclast, and material will migrate along the chemical potential gradient towards this zone. Deposition of material within this zone may either be due to precipitation, metasomatic replacement

or metamorphism of matrix material, or recrystallization of a pressure fringe (Hamner and Passchier, 1991).

The orientation of pressure shadows relative to the stiff inclusion can reveal shear sense. Assuming a horizontal plane of shear, a pressure shadow located to the left of its associated inclusion will indicate an anti-clockwise, or sinistral sense of shear, while a pressure shadow located to the right of the inclusion will indicate a clockwise, or dextral, sense of shear.

In the western portion of the Nowyak shear zone, thin-section scale winged porphyroclasts and pressure shadows are preserved displaying a consistent sinistral shear sense, indicating top-to-the-north sense of motion (Plate 4-8 - 4-11). Labelle (1997) also documents a similar top-to-the-north sense of shear from porphyroclasts located in the eastern portion of the shear zone.

4.3.3 Strain gradient

The Nowyak shear zone occurs along the southern portion of the Kaminak Lake greenstone belt. Within unstrained hanging-wall volcanoclastic rocks, the main foliation is defined by the alignment of plagioclase, amphibole, biotite, and recrystallized quartz. With increasing proximity towards the Nowyak shear zone, volcanoclastic rocks display progressively increasing amounts of strain and development of mylonite fabrics, with a decrease in relict porphyroclast/matrix ratio and in overall grain size (Plates 4-12, 13). Near the southern boundary of the shear zone, the metagranite also shows strain gradient, progressing from an S>L tectonite, defined by closely spaced (<1cm) mafic and felsic compositional layers containing elongate aggregates of biotite, plagioclase and

quartz, to a strongly mylonitized metagranite, defined by elongate aggregates of biotite and quartz ribbons.

Annealing through recovery and static recrystallization of deformed mylonitic grains is evident in portions of the Nowyak shear zone. Growth of new grains, healing of internal defects, and the straightening of grain boundaries (Plate 4-14, 15, 16) obliterate relict strain fabrics (Plate 4-17), and indicate recovery after deformation. Late hornblende growth overprints S_{my} , indicating metamorphism outlasted deformation (Plate 4-18).

4.5 Analysis of structural data

The Nowyak shear zone is a shallowly north-plunging ductile shear zone. Down-dip extension lineations and north-side down kinematic indicators on the north, northwest, and northeast sides of the Nowyak shear zone indicate that it is either a normal fault or a folded thrust fault with top-down-to-the-north movement. A low-strain carbonate enclave, interpreted by Relf et al. (1997) to be derived from the Hurwitz Group, constrains motion on the Nowyak shear zone to be Proterozoic in age. Within the shear zone and its associated footwall rocks, the curvilinear foliation generally strikes north-northeast in the west, and north-northwest in the east.

A strong, penetrative mineral and stretching lineation is documented throughout the shear zone and associated footwall rocks, but not within hanging-wall rocks. On a map-scale, the lineation generally trends north-northwest ($23^\circ/342^\circ$), with a small deviation in the western portion of the shear zone where lineations trend to the north-northeast. On a stereonet projection (Figure 4-2, 4-3), the main lineation cluster is moderately dispersed. If the lineations originally clustered then dispersion is consistent

with lineation development prior to a folding event. A similar foliation and lineation dispersion pattern could have been produced by diapiric emplacement of the metagranitic pluton within the footwall (Labelle, 1997). This interpretation, however, is inconsistent with timing relationships known for the area, that indicate that the metagranite is significantly older than the latest motion of the Nowyak shear zone. The metagranite yields a 2.64 Ga U-Pb crystallization age (MacLachlan, in preparation, 2001), whereas the latest motion on the Nowyak shear zone is constrained to be younger than the Proterozoic carbonate enclave (Relf et al., 1997).

Stereonet projections (Figure 4-5) of poles to foliations disperse about a girdle of a great circle, suggesting a map-scale fold with a fold axis oriented at $21^{\circ}/006^{\circ}$. This result suggests that both the shear zone and footwall rocks have been folded following the formation of the S_{my} and S_m . This map-scale fold is similar in orientation to S_{my+1} folds observed within the Nowyak shear zone.

Within the Nowyak complex, two sets of folds can be distinguished. Intrafolial F_{my-1} folds are transposed by the shear foliation, and are only observed within the Nowyak shear zone. Isoclinal to tight F_{my+1} and F_{m+1} folds fold S_{my} and S_m , respectively. Stereonet projections of F_{my+1} folds for the Nowyak shear zone show that F_{my+1} fold hinges are generally collinear to the fold axis calculated by the dispersion of the S_{my} foliation. A km-scale map fold, the fold axis of which is $21^{\circ}/006^{\circ}$, is similar in orientation to F_{my+1} folds. Together, these folds are tentatively interpreted to have folded the Nowyak complex and the Nowyak shear zone (Figure 4-5). The relationship between folds within the Nowyak complex and larger-scale regional folds is ambiguous.

Figure 4-5 displays three outliers interpreted to represent F_{my-1} folds that have been transposed into the S_{my} foliation during the ductile shearing event. Their relationship to folds in the hanging wall is unclear. F_{m+1} and F_{my+1} folds of the footwall and shear zone are similar in orientation to the F_3 regional folding event mapped by Relf et al. (1997; 1998; 1999).

4.6 Summary

Generally, foliations within the Nowyak complex strike north-northeast to north-northwest, and dip moderately towards the north. The complex is defined by a shallowly north-plunging, penetrative, mineral and stretching lineation that occurs within rocks of both the footwall and the shear zone, but is notably absent within surrounding rocks of the hanging wall. The hanging wall include rocks from the Yathkyed Lake and the Kaminak Lake greenstone belts and Hurwitz Group rocks. The Yathkyed Lake greenstone belt ranges from southwest-striking in the west to west-striking in the east (Relf et al., 1998; 1999), where S_{main} is defined by alignment of metamorphic minerals at greenschist to upper-amphibolite grade (MacLachlan et al., 2000). S_{main} within the Kaminak Lake greenstone belt is defined by the orientation of metamorphic minerals, and may be correlative with S_{main} in the Yathkyed Lake greenstone belt. The Hurwitz Group overlies the contact between the Yathkyed Lake and Kaminak Lake greenstone belts.

Hanging wall and footwall rocks are separated by the shallowly north-plunging Nowyak shear zone. Down-dip extension lineations and north-side down kinematic indicators preserved on the north, northwest, and northeast sides of the shear zone indicate a normal sense of movement that could have been produced either a normal or

folded thrust fault. Stereonet projections of poles to foliations are dispersed about a great circle, as do lineations, suggesting that the shear zone was subsequently folded post- S_{my} . Along the eastern limb of the map scale fold, metamorphism outlasted deformation, as indicated by late hornblende overprinting the S_{my} fabric. Footwall and shear zone rocks preserve two sets of folds: F_{my-1} are relict, pre- S_{my} folds which cannot be related to any map structures. F_{my+1} (shear zone) and F_{m+1} (footwall) fold S_{my} and S_m , respectively, and are tentatively correlated to large scale F_3 regional folds.

Figure 4-1: Simplified structural geology of the Nowyak Lake area, modified from Relf et al., 1996.

A) Mineral lineations in granite

Average orientation:
27°/345°

N=7

B) Mineral lineations in the Stonecutter supracrustal unit

Average orientation:
13°/329°

N=3

C) Nowyak footwall: poles to S_m

Average orientation:
266°/23°

N=13

Legend

- ☆ Granite
- ◆ Garnet amphibolite
- ◇ Pelitic schist

Figure 4-2: Stereonet projections (S_m) for Nowyak footwall rocks. (a) Mineral lineations in metagranite; (b) Mineral lineations in the Stonecutter supracrustal unit; (c) Poles to S_m .

A) Stretching lineations in chlorite mylonite

Average orientation:
24°/345°

N=12

B) Mineral lineations in chlorite mylonite

Average orientation:
24°/341°

N=7

C) Mineral lineations in low-strain amphibolite enclaves

Average orientation:
21°/345°

N=7

Legend

- Chlorite mylonite (terMeer, 1998)
- Chlorite mylonite (LaBelle, 1997)
- ⊕ Amphibolite (terMeer, 1998)
- ⊕ Amphibolite (LaBelle, 1997)

Figure 4-3: Stereonet projections for mineral and extensional lineations within the Nowyak shear zone. (a) Extension lineations for chlorite mylonite; (b) Mineral lineations for chlorite mylonite; (c) Mineral lineations for amphibolite enclaves.

A) Nowyak shear zone: poles to S_{my}
chlorite mylonite

N=27

B) Nowyak shear zone: poles to S_{my}
amphibolite enclave

N=13

Figure 4-4: Stereonet projections (S_{my}) for the Nowyak shear zone. (a) Poles to S_{my} for chlorite mylonite; (b) Poles to S_{my} for amphibolite enclaves.

A) Nowyak shear zone: F_{my+1} and F_{my-1} fold axis

Average orientation of cluster:
31°/003°

N=8

B) Nowyak complex: poles to S_m and S_{my}
calculated girdle: 096°/69°
 F_{my+1} fold axis: 21°/006°

N=53

Legend

- ☆ Granite
- ◆ Garnet amphibolite
- ◇ Pelitic schist
- Chlorite mylonite (terMeer, 1998)
- Chlorite mylonite (LaBelle, 1997)
- ⊕ Amphibolite (terMeer, 1998)
- ⊕ Amphibolite (LaBelle, 1997)

Figure 4-5: Stereonet projections and interpretation for the Nowyak complex. (a) F_{my+1} and F_{my-1} fold axis; (b) Poles to S_{my} and S_m .

Plate 4-1: Northward view of garnet amphibolite; open, F_{m+1} shallowly north-plunging fold.

Plate 4-2: Chlorite mylonite; isoclinal to tight post F_{m+1} fold. Penetrative axial planar cleavage parallel to S_m . Coin is 3 cm in diameter.

Plate 4-3: Thin section of chlorite mylonite, MT98-127. Rootless, F_{m+1} isoclinal fold defined by folded layer of recrystallized quartz and elongate hornblende and chlorite grains. Cross polars, 2.4 mm field of view.

Plate 4-4: Thin section of chlorite mylonite, MT98-109. Rootless, F_{m+1} isoclinal fold defined by recrystallized quartz and elongate hornblende and chlorite grains. Cross polars, 4.8 mm field of view.

Plate 4-5: Thin section of chlorite mylonite, MT98-129. Eastward view of asymmetrical extensional shear band, observed in the XZ plane of the finite strain ellipsoid. Interpreted to have a top-to-the-north sense of shear. Cross polars, 4.8 mm field of view.

Plate 4-6: Thin section of chlorite mylonite, MT98-129. Eastward view of asymmetrical extensional shear band, observed in the XZ plane of the finite strain ellipsoid. Interpreted to have a top-to-the-north sense of shear. Cross polars, 4.8 mm field of view.

Plate 4-7: Thin section of chlorite mylonite, MT98-118. Eastward view of asymmetrical extensional shear band, observed in the XZ plane of the finite strain ellipsoid. Interpreted to have a top-to-the-north sense of shear. Cross polars, 4.8 mm field of view.

Plate 4-8: Thin section of chlorite mylonite, MT98-129. Eastward view of sigma-type hornblende porphyroclast, observed in the XZ plane of the finite strain ellipsoid. Interpreted to have a top-to-the-north sense of rotation. Crossed polars. 1.2 mm field of view.

Plate 4-9: Thin section of chlorite mylonite, MT98-129. Eastward view of sigma-type plagioclase porphyroclast, observed in the XZ plane of the finite strain ellipsoid. Interpreted to have a top-to-the-north sense of rotation. Crossed polars. 1.2 mm field of view.

Plate 4-10: Thin section of chlorite mylonite, MT98-118. Eastward view sigma-type plagioclase porphyroclast, observed in the XZ plane of the finite strain ellipsoid. Interpreted to have a top-to-the-north sense of rotation. Crossed polars. 2.4 mm field of view.

Plate 4-11: Thin section of chlorite mylonite, MT98-129. Eastward view of sigma-type plagioclase porphyroclast, observed in the XZ plane of the finite strain ellipsoid. Interpreted to have a top-to-the-north sense of rotation. Crossed polars. 1.2 mm field of view.

Plate 4-12: Thin section of chlorite mylonite, MT98-109. S_{my} fabric. Cross polars, 4.8 mm field of view.

Plate 4-13: Thin section of chlorite mylonite, MT98-129. With progressive strain, grain-size reduction and increased foliation intensity lead to the development of a mylonite. Cross polars, 4.8 mm field of view.

Plate 4-14, 15, 16: SEM images of chlorite mylonite, thin section MT98-137. Growth of new grains, healing of internal defects, and the straightening of grain boundaries indicates recovery after deformation.

Plate 4-17: Thin section of chlorite mylonite, MT98-137. Predominantly annealed with a layer of relict (?) strained fabric preserved within. Late hornblende cross-cuts foliation, indicating metamorphism outlasted deformation. Cross polars, 4.8 mm field of view.

Plate 4-18: Thin section of chlorite mylonite cut parallel to S_{my} , MT98-137. Coarse-grained hornblende overprints chlorite matrix, indicating metamorphism outlasted deformation. Cross polars, 4.8 mm field of view.

CHAPTER SIX: METAMORPHISM OF THE NOWYAK COMPLEX

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CHAPTER 5: METAMORPHISM OF THE NOWYAK COMPLEX

5.1 Introduction

The Nowyak shear zone juxtaposes mid-amphibolite grade, footwall rocks against greenschist-to-lower amphibolite grade, hanging wall rocks. The aim of this chapter is to characterize and compare the metamorphic history of rocks within the Nowyak complex to its surrounding rocks. Petrographic evidence is used to determine the relative timing of metamorphism with respect to deformation. Thermobarometry is used to deduce differences in temperature and pressure conditions across the Nowyak complex (Figure 5-1).

5.2 Petrography

Thin section petrographic observations are summarized below, for hanging wall, shear zone, and footwall rocks. Hanging wall rock consists mainly of metavolcaniclastic and metasedimentary rocks at greenschist to lower-amphibolite facies. Shear zone rocks include chloritic schist with lower-strain amphibolite enclaves. Footwall rocks consist dominantly of a two-mica metagranite, with a thin lens of biotite-muscovite schist and two volumetrically minor, but petrologically important, supracrustal enclaves. The supracrustal enclaves consist of psammite, semi-pelite, and pelite schist interlayered at a scale of metres to tens of metres with amphibolite, garnet amphibolite, and amphibolite gneiss. Mineral assemblages for individual samples are presented in Appendixes A, B, and C.

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5.2.1 Hanging wall rocks

Immediately adjacent to the Nowyak complex, both the Kaminak Lake and the Yathkyed Lake greenstone belt commonly contain the mineral assemblage actinolite + plagioclase + chlorite + quartz. Minerals in minor abundance include calcite, biotite, and opaque minerals. Five samples, three of which were taken from the regional mapping collection of Relf et al. (1996), were studied petrographically.

I. Yathkyed Lake greenstone belt

Approximately 30 km to the north of the Nowyak complex, mafic volcanic rocks preserve an hornblende-in isograd, characterized by hornblende + garnet and hornblende + garnet + epidote assemblages (Relf et al., 1998; see Appendix B for mineral assemblages and modal abundances). The highest grade rocks occur further north along the northwest side of the Tyrrell shear zone; Relf et al. (1998) suggest that metamorphic conditions may have reached uppermost amphibolite to granulite facies.

Most metavolcanic rocks are moderate to extremely fine-grained and consist of clinozoisite-epidote (generally $< 50 \mu\text{m}$), quartz, and plagioclase (see Appendix A for mineral assemblages and modal abundances). In one lower-amphibolite grade sample (MT98-155, ~ 1 km NW of the Nowyak complex), medium grained, subhedral to euhedral plagioclase, hornblende, and quartz phenocrysts are preserved (Plate 5-1). Short, discontinuous recrystallized quartz veins lie parallel to the main foliation (S_{m1} , see Chapter 4). Minerals in minor abundance include calcite and pyrite.

One sample (CR96-1302), an amphibolite-grade sample approximately 5 km NW of the Nowyak complex, consists nearly entirely of randomly oriented, coarse grained (up

to 2 cm in length), hornblende (~ 60%) and actinolite (~ 30%). Fractures contain fine grained, randomly oriented, recrystallized quartz and calcite grains.

II. Kaminak Lake greenstone belt

Metavolcanic rocks are fine to medium grained, and consist of plagioclase, amphibole, biotite, and recrystallized quartz, the orientation of which broadly defines the main foliation (S_{main}). Subhedral to euhedral amphiboles generally consist of actinolite cores surrounded by hornblende rims. Matrix amphiboles envelop relict plagioclase phenocrysts. Minerals in minor abundance include calcite and pyrite.

Relf et al. (1997), interpreted the formation of S_{main} within the Yathkyed Lake greenstone belt, to have been coeval with regional, greenschist-grade metamorphism on the basis that S_{main} is defined by thermal peak mineral assemblages. Relf et al. (1997) note that although S_{main} within the Yathkyed belt is similar in appearance to S_{main} within the Kaminak belt, it is not clear whether the two formed at the same time, as the contact between the two belts is covered by rocks of the Hurwitz Group.

6.2.2 Nowyak shear zone

The Nowyak shear zone has mineral assemblages which indicate a retrograde transition from lower amphibolite to greenschist facies. The reaction for this transition may be: *hornblende* + *plagioclase* + H_2O = *chlorite* + *epidote* + *quartz*. Most of the shear zone is at greenschist grade, with a mineral assemblage of chlorite + quartz + plagioclase ± calcite ± actinolite ± hornblende ± opaques + epidote (see Appendix B for mineral assemblages and modal abundances). Chlorite is medium to coarse grained. The orientation of mafic and felsic layers and of platy minerals define the main (S_{my}) foliation.

Relict plagioclase phenocrysts show minor to moderate alteration to sericite, and medium to coarse grained sub-euhedral actinolite and hornblende crystals display intense retrogression to chlorite.

Small amphibolite enclaves, varying from approximately 10 to 120 metres in length, occur throughout the shear zone. They contain a mineral assemblage of hornblende + plagioclase + quartz + chlorite $\pm$ actinolite $\pm$ calcite $\pm$ opaques + epidote (see Appendix B for mineral assemblages and modal abundances). The main foliation is defined by the orientation of coarse-grained hornblende, fine-grained chlorite, and interlocking aggregates of recrystallized plagioclase and quartz. Hornblende and actinolite crystals are folded and fractured, indicating the deformation outlasted the amphibolite-facies metamorphism. However, on the western side of the shear zone, coarse-grain hornblende rosettes overgrew the chlorite foliation. This indicates that (1) metamorphism outlasted deformation, possibly indicating differential uplift of the limbs of the folded shear zone, or (2) a second, prograde, metamorphic event occurred post deformation, or (3) recrystallization was controlled by local conditions (e.g. fluids).

6.2.3 Footwall rocks

I. Nowyak metagranite

Metagranite commonly contains the mineral assemblage quartz + potassium feldspar + plagioclase + biotite $\pm$ muscovite $\pm$ chlorite (see Appendix C for mineral assemblages and modal abundances). Minerals in minor abundance include pyrite, apatite, titanite, and zircon. Fine to medium-grained biotite and muscovite within the granoblastic quartz-feldspar matrix define a moderate to strong S_m schistosity. Grain

size of matrix crystals is variable, ranging from coarse-grained (~ 1 cm), relatively unstrained euhedral grains, to fine-grained (< 1mm) recrystallized aggregates.

Coarse-grained microcline crystals contain plagioclase inclusions (Plate 5-2), and occasional display a myrmekitic texture, in which vermicular quartz is intergrown with plagioclase and adjacent potassium feldspar (Plate 5-3). This texture is commonly found in high-grade quartzo-feldspathic gneisses, and is generally ascribed to the breakdown of igneous potassium feldspar (Barker, 1990), or within greenschist-facies rocks that have undergone ductile strain (Simpson, 1985). The presence of plagioclase, quartz, biotite, and muscovite is indicative of amphibolite-facies metamorphism. Variable retrogression is evidenced in biotite replacement to chlorite.

II. Garnet Amphibolite

Garnet amphibolite commonly contains the mineral assemblage hornblende + quartz + plagioclase + epidote $\pm$ biotite $\pm$ chlorite $\pm$ zoisite (see Appendix C for mineral assemblages and modal abundances). Minerals in minor abundance include calcite (usually occurring within secondary veins), rutile, ilmenite, apatite, and zircon. Some samples contain idioblastic hornblende and lack biotite, while others contain idioblastic to embayed hornblende with a lesser amount of biotite. The presence of garnet, hornblende, epidote, and plagioclase is indicative of epidote-amphibolite-facies metamorphism. As Spear (1993) demonstrates, at pressures above 3.3 kbar, the chlorite-out reaction intersects epidote-out reactions (Figure 2-2). The more shallow slopes of the epidote-out reactions relative to chlorite-out cause epidote to persist above the breakdown

of chlorite giving rise to assemblages typical of the epidote-amphibolite facies (Figure 5-2; Spear, 1993).

The peak metamorphic mineral assemblage in garnet amphibolite includes garnet, hornblende, plagioclase, and quartz, all aligned in S_m . Garnet growth is interpreted as syn- S_m , based on the presence of quartz and plagioclase inclusion trails (S_i) which are parallel to S_m , while S_m envelops garnet porphyroblasts (Plate 5-4 and 5-5; Figure 5-3). Biotite grains generally lie oblique to S_m , indicating post- S_m peak metamorphic growth, and are not considered to be in equilibrium with the above mineral assemblage (Plate 5-6).

Garnet porphyroblasts, generally <1.5 cm in diameter, predominately display two different textures: (1) unaltered euhedral crystals, and (2) rounded and often skeletal porphyroblasts (Plate 5-7) that have been resorbed up to 25% by a breakdown reaction producing plagioclase and hornblende. Garnet breakdown zones consist of a fine-grained, randomly oriented intergrowth of hornblende, plagioclase, and quartz. Poikiloblastic garnets contain up to 60% inclusions of quartz, plagioclase, epidote, and ilmenite. Garnet porphyroblasts are transected by randomly oriented fractures, containing fine to medium-grained hornblende, and fine-grained recrystallized quartz, plagioclase, and biotite. Plagioclase occasionally forms partial moats around garnets (Plate 3-8), and may be the result an idealized reaction like: *tschermakitic-hornblende* + *garnet* + *quartz* = *tremolitic-hornblende* + *plagioclase*.

Plagioclase and quartz make up 20 - 40% of the garnet amphibolite. Plagioclase and quartz occurs both within the matrix, and within partial moats around some garnet

porphyroblasts. Within the matrix, plagioclase occurs as medium-grained, euhedral crystals up to 5 mm in length, whereas within garnet breakdown zones, plagioclase is generally anhedral and extremely fine-grained. Granoblastic quartz grains have been partially to fully recrystallized.

Most garnet amphibolite contain > 50% hornblende (< 1 cm in length). Grains are equigranular, and the majority have sharp grain boundaries with adjacent grains of plagioclase and quartz. Some grains show quartz and plagioclase-filled embayments, and also contain inclusions of quartz and rare plagioclase (Plate 5-9). Hornblende is usually evenly distributed within a sample, but occasionally forms discrete gneissic bands with alternating layers of quartz and feldspar.

Biotite makes up to 10% of the garnet amphibolites. Most biotite is subidioblastic, and contains radiogenic halos around zircon inclusions. In some samples, small amounts of biotite are aligned with the hornblende along the main foliation, but most biotite grains are at an oblique angle to the foliation (Plate 5-10), or within fractures and reaction rims of garnet.

Retrograde metamorphism is evidenced by common breakdown of garnet rims to a moat of fine-grained, randomly oriented plagioclase, hornblende, and quartz. Matrix biotite shows some retrogression to chlorite, and is most pronounced along garnet fractures and within garnet pressure shadows.

III. Pelite schist

Pelite schists in the Nowyak complex contain the assemblage quartz - plagioclase - biotite - muscovite $\pm$ garnet $\pm$ kyanite (see Appendix C for mineral assemblages and

modal abundances). This assemblage is diagnostic of middle amphibolite-facies metamorphism (Figure 5-4). No evidence for partial melting is observed in either field or petrography studies, indicating maximum temperature constraints of $< 680^{\circ}\text{C}$. Minerals in minor abundance include chlorite, ilmenite, rutile, apatite, titanite, zircon, and monazite.

A well-developed S_m fabric is defined by the orientation of kyanite, muscovite, biotite, plagioclase, and quartz. A weakly developed S_{m+1} is defined by the crenulation of the S_m fabric (Plate 5-10). The earliest fabric (S_i) recognized in thin-section occurs as straight and curved inclusion trails of quartz, biotite, and plagioclase within garnet porphyroblasts. The main foliation wraps around the garnet, indicating that S_m development likely outlasted garnet growth (Plate 5-11; Figure 5-3).

Garnet occurs as subidioblastic to idioblastic porphyroblasts and poikiloblasts, ranging in size from 0.5 cm to 1.5 cm in diameter. Poikiloblastic grains contain up to 70% inclusions of quartz, plagioclase, and biotite. Inclusion trails are either straight or curved, and in some crystals can be traced into the matrix (Plate 5-12). Curved inclusion trails indicate the main fabric changing orientation relative to the growing garnet (Bell, 1985), rotation of the porphyroblast during growth, or that garnet overgrew folds (Figure 6-3). One garnet porphyroblast, 7.5 mm in diameter, displays a snowball fabric with a rotation greater than 180 degrees.

Garnet is often rimmed (Plate 5-13 and 5-14), or has been entirely consumed to produce a breakdown zone of variable width, consisting of randomly oriented biotite, muscovite, plagioclase, and quartz (generally < 1 mm in width). Garnet fractures,

generally oriented approximately 0 - 30 degrees to S_m , also contain randomly oriented, fine-grained biotite, muscovite, quartz and plagioclase.

On an outcrop scale, kyanite is found sporadically within pelitic schists, but where present can make upwards of 15 - 20 % of the rock. It is coarse-grained, up to 1 cm in length, and lies within the main foliation. Xenoblastic to subidioblastic kyanite grains occasionally display kinking and undulose extinction, reflecting strain after metamorphic growth.

Quartz and plagioclase make up 30 -35 % of most samples. Anhedral quartz is partially to fully recrystallized, and occurs within the matrix, garnet breakdown zones, and as discrete veins oriented approximately parallel to the main foliation. Fine to medium-grained plagioclase porphyroblasts are subhedral to anhedral, and together with recrystallized quartz, form discrete felsic-rich layers. Fine-grained, randomly oriented plagioclase and quartz also occur within the garnet breakdown zone.

Mica makes up 25 - 35% of pelite schist. The majority of biotite and muscovite is medium grained and idioblastic, and biotite grains contain halos around zircon inclusions. The orientation of both biotite and muscovite defines the main foliation (S_m); however, a small amount of biotite lies oblique to S_m . Fine grained, randomly oriented biotite and muscovite occur in garnet breakdown zones, and there are rare biotite inclusions within garnet. Biotite inclusions are not surrounded by quartz or plagioclase, thereby negating their use in calculating peak metamorphic conditions.

Ilmenite is more common than rutile in the pelite schist. Subhedral to anhedral, ilmenite and rutile are fine-grained, < 500 μm in diameter, and usually do not occur

within the same microdomains. However, in one location within the matrix, a rutile crystal is surrounded by a rim of ilmenite (Plate 5-13), which may be a result of the idealized, decompression reaction:

Retrograde metamorphism is evidenced by breakdown of garnet rims to a fine-grained mixture of randomly oriented plagioclase, quartz, muscovite, and biotite. Matrix biotite shows some retrogression to chlorite, which is most pronounced along garnet fractures and within garnet pressure shadows.

5.3 Geothermobarometry

5.3.1 Methodology

P-T conditions within and surrounding the Nowyak complex were assessed on the basis of detailed petrology, mineral chemistry, and geothermobarometry. Compositional data and geothermobarometric calculations from twelve samples are presented: five are from the supracrustal enclave within the Nowyak footwall, four are from the Nowyak shear zone, and three are from the hanging wall (Figure 5-1). Electron distribution images and x-ray maps were produced at the Geological Survey of Canada using a Scanning Electron Microscope (SEM), in order to fully characterize compositional zoning of garnet, its relationship to textural features, and to guide quantitative analysis. Mineral analyses were carried out at both the Geological Survey of Canada (GSC) and Carleton University. At the GSC, a Cameca SX-50 microprobe, equipped with 4 wavelength dispersive spectrometers, was used. Operating conditions were 20kV, 10nA, with a 10 second peak counting time. A focused beam (~1 µm) was used for all analyses except

feldspar (10 μm spot size). The standards were a mix of natural and synthetic metals and silicate compounds. Data was reduced using the ZAF correction procedures of Armstrong (1988). At Carleton University, a Camebax MBX microprobe, equipped with 4 wavelength dispersive spectrometers, was used. Operating conditions were 15kV and 15nA, with a 15 second peak counting time. A focused beam ($\sim 1 \mu\text{m}$) was used for all analyses except feldspar (10 μm spot size). A well characterized suite of natural and synthetic minerals and compounds were used as calibration standards. Data were reduced by the Cameca PAP correction program. A summary of mineral analyses used in geothermobarometric calculations are given in Tables 1 and 2. For consistency with thermodynamic calibrations in TWEEQU (Berman, 1991; Thermobarometry With Estimation of Equilibrium state), all Fe was assumed to be Fe^{2+} . For each sample, at least two to four domains containing the required assemblage were analysed and used for geothermobarometric calculations in order to test for consistency at the thin section scale.

Pressures and temperatures were generated using TWEEQU software of Berman (1991). This program is designed to provide thermobarometric consistency by calculating the location of equilibria in P-T space using a set of internally consistent thermodynamic data for phase-end member and solution properties.

For a system at chemical equilibrium, the chemical potentials of all system components are equal in all phases, and balanced chemical equilibria can be written among the end members of each phase. For each equilibrium, the following equation is solved for P and T by TWEEQU:

$$\Delta G(P,T) = 0 = \Delta H(298.15,1) + \int_{298}^T \Delta C_p dT + \int_1^P \Delta V dP - T \{ \Delta S(298.15,1) + \int_{298}^T (\Delta C_p / T) dT \} + RT \ln K_{eq}$$

where ΔG , ΔH , ΔS , ΔV , ΔC_p refer to the free energy, enthalpy, entropy, volume, and heat capacity of the reaction (Spear, 1993), respectively, and R is the gas constant. K_{eq} is the equilibrium constant, which equals the product of the activities of the phase components, or phase raised to the power of its reaction coefficient.

TWEEQU allows the user to calculate as many equilibria as possible, both stable and metastable, however, not all of these are independent. In this study, only the most robust thermobarometers and barometers, selected on the basis of reaction properties and calibration systematics, were applied. TWEEQU version 1.02 was used for all calculations. This version utilizes thermodynamic data for end members of Berman (1988; 1990), and the solution models of Berman (1990), McMullin and others (1991), Fuhrman and Lindsley (1988), and Mader et al. (1994) for garnet, biotite, plagioclase and hornblende, respectively. All equilibria presented in this study are listed with the higher temperature assemblage on the right hand side.

Thermometry of pelitic schists was based on the garnet-biotite exchange equilibrium:

almandine + phlogopite = pyrope + annite.

Barometry was based on the GASP net-transfer equilibria:

3 anorthite = grossular + 2 aluminosilicate + quartz, and

annite + 3 anorthite = muscovite + grossular + almandine. For rocks containing kyanite, pressures were calculated taking an average of reactions 2 and 3. Reaction 3 was solely used for rocks lacking kyanite.

Thermometry of garnet amphibolites was based on the garnet-hornblende exchange thermometer:

5 almandine + 3 tremolite = 3 Fe-tremolite + 5 pyrope,

as well as the amphibole-plagioclase thermometers of Holland and Blundy (1994):

edenite + 4 quartz = tremolite + albite, and

edenite + albite = richterite + anorthite.

The latter equilibria allow temperatures to be computed for garnet -free amphibolites of the Nowyak shear zone and hanging wall rocks.

As reaction 6 does not require the presence of quartz, and can be applied to silica-undersaturated rocks, Holland and Blundy (1994) suggest it is most reliable for high-temperature rocks where anorthite-rich feldspars predominate, and/or under conditions of low silica activity. However, the activity coefficient of anorthite is less well determined than that of albite, and rocks containing nearly pure albite will lead to large uncertainties in anorthite activity (Holland and Blundy, 1994). Accordingly, Holland and Blundy

(1994) suggest reaction 5 be used in low temperature metamorphic rocks containing albitic plagioclase. Table 5-1 summarizes anorthite contents, and resulting edenite-tremolite (equation 5) vs. edenite-richterite (equation 6) temperature calculations for footwall and shear zone amphibolites, and garnet amphibolites within the hanging wall.

In general, X_{An} in footwall and shear zone amphibolites range from 0.68 - 0.76, and 0.57 to 0.76, respectively. Anorthite contents within garnet amphibolites range between $X_{An}=0.33$ - 0.57. As Nowyak amphibolite and garnet amphibolite rocks contain intermediate plagioclase far removed from both albite and anorthite end members, either thermometer, or an average, may be suitable. A plot of T_{ed-tr} against T_{ed-ri} (Figure 5-5) indicates that reaction 6 yields systematically lower temperatures than reaction 5, suggesting that the average of the two thermometers may not be the most reliable method. Overall, temperatures calculated via reaction 6 generally had less scatter than those calculated by reaction 5. This internal consistency suggests that reaction 6 is a more reliable thermometer, and it is these temperatures that are reported.

Within each microdomain, reaction 4 yields higher temperatures relative to those calculated with equilibrium 6. Both reactions 4 and 6 are exchange reactions, but differences in temperatures may reflect differences in the closure temperatures of the Fe-Mg and Na-Ca exchange reactions. Because reaction 4 is strongly affected by the oxidation state of iron in amphibole, which has not been measured and is only approximately constrained (Spear and Kimball, 1984), reaction 6 is considered to yield the most reliable temperatures.

Barometry of garnet amphibolites was carried out using TWEEQU to compute the position of a garnet-hornblende-plagioclase-quartz barometer:

3 tschermakite + 4 grossular + 2 pyrope + 12 quartz = 3 tremolite + 12 anorthite.

Reactions involving Fe-tschermakite were excluded in garnet amphibolites because thermodynamic data is less certain for this end-member than they are for other amphibole end-members (Mader et al., 1994).

5.3.2 Selection of equilibria

In garnet amphibolites, hornblendes and plagioclases from up to four different textural locations were analysed: (1) grains in contact with garnet porphyroblasts, where garnet shows no evidence of resorption, (2) proximal grains ~ 0.1 to 0.5 mm away from garnet rims and, in the case of hornblende, separated from other non-ferromagnesium minerals by plagioclase and/or quartz, (3) matrix grains further away from garnet, and (4) grains produced by breakdown of garnet rims to form hornblende and plagioclase.

Quantitative data for garnet, muscovite, biotite, and plagioclase were obtained for pelitic schists. In each thin section, biotites and plagioclases from up to six different textural locations were analysed: (1) grains in contact with garnet rims, (2) proximal grains ~0.1 to 0.5 mm away from the garnet rim and, in the case of biotite, separated from other Fe-Mg minerals by plagioclase and/or quartz, (3) matrix grains farther away from garnet porphyroblasts, (4) grains located in garnet pressure shadows, (5) grains found

within garnet breakdown zones, and (6) inclusions within garnet cores. Muscovite grains from both matrix and the garnet break down zones were also analysed.

A thorough examination of the composition of grains within these textural locations was completed (see thin section descriptions below), and in general, 3 domains for P-T calculations were identified. Where present, prograde conditions were calculated from garnet inclusions. This method is considered to be the only reliable method for calculating prograde conditions. However, as inclusions are very rare, prograde metamorphic conditions were also calculated assuming that the garnet core was in equilibrium with matrix grains far removed from the garnet porphyroblast. It should be noted that when tested on thin section BLB97-003a (see below), both techniques gave similar results.

Peak metamorphic conditions were calculated by assuming that with continued garnet growth, the garnet rim (generally close to the garnet rim, but not within the garnet breakdown zone; ~ 200 μm from the extreme garnet rim) was in equilibrium with the cores of matrix grains near the garnet (within 400 μm), but not texturally associated with the garnet breakdown zone. Matrix rims were avoided as there is evidence for chemical resetting during a later event (see thin section descriptions below). Breakdown conditions are best preserved within the pelite samples, and are recognized by a marked decrease in X_{Gr} of garnet, locally within fractures internal to garnet and at the extreme outer rim (<50 μm) of garnet, which is associated with an increase in X_{An} of adjacent plagioclase.

5.3.3 Hanging wall rocks

Chemical composition and temperature results

Three hanging wall samples, YD98-3044, IL96-2166 and CR96-0532, were analyzed for thermometry calculations (Figure 5-1). YD98-3044 is located within the northernmost portion of Yathkyed Lake greenstone belt, north of the hornblende-in isograd, within the upper tectonostratigraphic unit. A second sample (CS96-1302), located within the Yathkyed Lake greenstone belt approximately 5 km NW of the Nowyak complex, contains ~ 60% hornblende, 30% calcite, and 10% quartz, with calcite and quartz infilling fractures. The sample, however, contains no plagioclase, making it an unsuitable candidate for thermobarometry. The other two samples, IL96-2166 and CR96-0532, are located approximately 12 km NE of the Nowyak complex, within a portion of the Kaminak Lake greenstone belt that has been reworked at ca. 1.83 Ga (Sandeman, 2000).

YD98-3044

Within thin section YD98-3044, plagioclase grains range from $X_{An}=0.82-0.84$ for cores and $X_{An}=0.72-0.81$ for rims, and generally show a slight increase in anorthite content from rim to core. Adjacent hornblende grains range from $Fe/(Fe+Mg)=0.38-0.44$, and show a very slight increase in Fe content from rim to core. X_{Na} ranges from 0.34-0.44 for cores and 0.31-0.43 for rims, and generally display a decrease in sodium content from core to rim.

Temperatures were calculated using the *edenite + albite = richterite + anorthite* equilibrium of Holland and Blundy (1994). Four domains (four adjacent plagioclase-

hornblende grains) were selected, and results range from 730-770°C for core compositions and 730-760°C for rim compositions. Holland and Blundy (1994) note that the thermometer contains a $\pm 40^\circ\text{C}$ error at temperatures between 400-1000°C and pressures between 1-15 kbar. As such, the temperature difference between core and rim conditions is interpreted to be insignificant. An average temperature for both core and rim compositions is 745 ± 25 .

IL96-2166

Within thin section IL96-2166, plagioclase grains range from $X_{\text{An}}=0.28-0.32$ for rims and $X_{\text{An}}=0.24-0.33$ for cores. Plagioclase grains show inconsistent anorthite zoning patterns. In general, the anorthite content increases from core to rim, though some grains display a reverse trend. Adjacent hornblende grains range from $\text{Fe}/(\text{Fe}+\text{Mg})=0.65-0.69$, and show a very slight increase in Fe content from rim to core. X_{Na} ranges from 0.33-0.45 for cores and 0.33-0.45 for rims, and generally display an increase in sodium content from core to rim.

Results for four domains range from 560-605°C for rim compositions and 560-610°C for core compositions. The average temperature for both core and rim compositions is $580 \pm 30^\circ\text{C}$.

CR96-0532

Within thin section CR96-0532, plagioclase grains range from $X_{\text{An}}=0.27-0.28$ for rims and $X_{\text{An}}=0.26-0.30$ for cores. Similar to thin section IL96-2106, plagioclase grains show inconsistent anorthite zoning patterns. In general, the anorthite content increases from core to rim, though some grains display a reverse trend. Adjacent hornblende grains

range from $\text{Fe}/(\text{Fe}+\text{Mg})=0.37\text{-}0.59$, and show a very slight increase in Fe content from rim to core. X_{Na} ranges from 0.27-0.37 for cores and 0.32-0.37 for rims, and generally displays a decrease in sodium content from core to rim.

For four domains, results range from 550-620°C for core compositions and 575-610°C for rim compositions. The average temperature for both core and rim compositions is 590 ± 40 °C.

Summary

Unfortunately, samples collected from the hanging wall immediately north of the Nowyak shear zone were unsuitable for thermometry. Petrography studies indicate that the area experienced greenschist-facies metamorphism. Typical mineral assemblages contain epidote, amphibole, chlorite, and plagioclase, which likely reflects transition of greenschist to amphibolite facies: *chlorite + epidote = Al-amphibole* (Spear, 1993). Approximately 12 km NE of the shear zone, two samples analysed from the Kaminak Lake greenstone belt yield temperature results of 580 ± 30 °C and 590 ± 40 °C, respectively. This is consistent with the interpretation that the area experienced epidote-amphibolite to lower-amphibolite facies metamorphism.

From the northern portion of the Yathkyed Lake greenstone belt, within the upper tectonostratigraphic unit, thin section YD98-3044, yielded a temperature of 745 ± 25 °C. Relf et al. (1998) mapped an hornblende-in isograd to the south of this sample, and the high temperature preserved indicates upper-amphibolite facies metamorphism for the area. This is slightly higher than the 700 °C calculated by Berman (unpublished data, 2001) for psammitic to pelitic rocks.

5.4.3 Nowyak shear zone

Chemical compositions and temperature results

The Nowyak shear zone is an area of retrograde metamorphism,, having mineral assemblages which indicate a transition from lower amphibolite to greenschist facies during deformation. The majority of the shear zone contains the mineral assemblage chlorite + plagioclase + quartz $\pm$ actinolite $\pm$ biotite $\pm$ calcite, and is at greenschist grade. Amphibolite enclaves occur throughout the shear zone, and preserve typical mineral assemblages of hornblende + quartz + plagioclase + actinolite $\pm$ potassium feldspar + calcite $\pm$ biotite $\pm$ ilmenite. Four shear zone samples (Figure 5-1) were analyzed from the amphibolite enclaves for thermobarometry calculations. Samples MT98-129 and MT98-157 are from the western portion of the shear zone, whereas samples MT98-137 and MT98-135 are from the eastern portion of the shear zone (Figure 5-1).

MT98-135

Within thin section MT98-135, plagioclase grains range from $X_{An}=0.35-0.40$ for rims and $X_{An}=0.24-0.29$ for cores. In general, the anorthite content increases from core to rim. Adjacent hornblende grains range from $Fe/(Fe+Mg)=0.54-0.90$, and show a very slight increase in Fe content from rim to core. X_{Na} ranges from 0.32-0.37 for cores and 0.30-0.37 for rims, and generally display a decrease in sodium content from core to rim. Hornblende occurs as rosette clusters, and overprints an earlier chlorite fabric, indicating metamorphism outlasting deformation, or that the area experienced a second metamorphic event.

Results for four domains range from 560-590 °C for core compositions and 590-650 °C for rim calculations. The average temperature for core and rim compositions is 570 ± 20 °C and 620 ± 30 °C, respectively.

MT98-137

Within thin section MT98-137, plagioclase grains range from $X_{An}=0.32-0.43$ for rims and $X_{An}=0.22-0.27$ for cores. Similar to thin section MT98-137, the anorthite content generally increases from core to rim. X_{Na} ranges from 0.26-0.42 for cores and 0.28-0.40 for rims, and generally display a decrease in sodium content from core to rim. Adjacent hornblende grains lie within S_{main} , range from $Fe/(Fe+Mg)=0.46-0.60$, and show a very slight increase in Fe content from rim to core.

Results for four domains range from 525-560 °C for core compositions and 575-625 °C for rim compositions. The average temperature for core and rim compositions is 545 ± 15 °C and 610 ± 35 °C, respectively.

MT98-129

Within thin section MT98-129, plagioclase grains range from $X_{An}=0.28-0.26$ for rims and $X_{An}=0.28-0.34$ for cores. Similar to the previously described samples, the anorthite content generally increases from core to rim. Adjacent hornblende grains lie within S_{main} , range from $Fe/(Fe+Mg)=0.53-0.59$, and show a very slight increase in Fe content from rim to core. X_{Na} ranges from 0.36-0.39 for cores and 0.34-0.40 for rims, and generally displays a decrease in sodium content from core to rim.

Results for four domains range from 575-625 °C for core compositions and 580-595 °C for rim compositions. The average temperature for core and rim compositions is 600 ± 25 °C and 590 ± 10 °C, respectively.

MT98-157

Within thin section MT98-157, plagioclase grains range from $X_{An}=0.29-0.36$ for rims and $X_{An}=0.31-0.40$ for cores. Similar to the previously described samples, the anorthite content generally increases from core to rim. Adjacent hornblende grains lie within S_{main} , range from $Fe/(Fe+Mg)=0.46-0.53$, and show a very slight increase in Fe content from rim to core. X_{Na} ranges from 0.28-0.40 for cores and 0.29-0.37 for rims, and generally displays a decrease in sodium content from core to rim.

Results for four domains range from 625-660 °C for core compositions and 620-650 °C for rim compositions. An average temperature for core and rim compositions is 650 ± 25 °C and 640 ± 20 °C, respectively.

Summary

Holland and Blundy (1994) note that the *edenite + albite = richterite + anorthite* thermometer contains a ± 40 °C error at temperatures between 400-1000 °C and pressures between 1-15 kbar. The four samples analysed from the Nowyak shear zone give temperatures ranging from 545 ± 15 °C - 650 ± 20 °C for core calculations and 590 ± 10 °C - 640 ± 20 °C for rim analysis. Calculations made with rim analysis are generally considered to be most robust, as exchange reactions occur within a relatively small distance (10-50 μm). The best estimate for the temperature experienced by the Nowyak shear zone, prior to greenschist-facies retrograde metamorphism, is preserved within

amphibolite enclaves. The temperature is calculated by averaging temperatures for all rim calculations is ~ 615 °C. The highest temperature recorded is a rim calculation for thin section MT98-157, which yields a temperature of 640 ± 20 °C.

Along the eastern side of the Nowyak shear zone, hornblende occurs as rosette clusters which overgrew the main chloritic fabric. This suggests that the shear zone may have either experienced one prolonged metamorphic period which outlasted deformation, a second, post-deformation metamorphic event, or that local mineral growth may be controlled by hydrothermal fluids. Petrography does not allow for a local distinction between the models, however, regional geology does lend support for a second metamorphic event. This will be discussed in chapter 7.

5.4.4 Footwall rocks

I. Garnet amphibolite

As discussed above, garnet amphibolites contain the phase assemblage hornblende + quartz + plagioclase $\pm$ biotite $\pm$ chlorite $\pm$ epidote. Garnet porphyroblasts, ranging from 1.5 mm to 1.5 cm in diameter, vary from euhedral to embayed due to the partial resorption by a reaction like #4, the products of which are plagioclase and hornblende. The garnet breakdown zone ranges from 50 μ m to 700 μ m in width. Garnet porphyroblasts contain plagioclase, quartz, epidote and hornblende inclusions. Garnet growth is interpreted as syn- S_m , based on the presence of quartz and plagioclase inclusion trails which are parallel and continuous with S_m , while S_m envelops garnet porphyroblasts (Figure 5-3).

Compositional variations of major phases for garnet amphibolites are presented in order to assess overall variability and to guide selection of mineral compositions that are assumed to have been in equilibrium, and are used in P-T calculations.

Chemical composition and P-T results

Thin section MT98-102

Three garnet porphyroblasts, and surrounding minerals, were analysed from thin section MT98-102 (Figure 5-6). Porphyroblasts range in diameter from 1.5 to 2.0 mm, and display narrow breakdown zones (100-300 μm in width) consisting of a randomly oriented, fine-grained mixture of plagioclase, hornblende, and quartz. The three garnet porphyroblasts display similar compositional profiles. Fe/(Fe+Mg) ratios decrease from core to rim (0.86-0.80), whereas grossular generally increases from core to rim (0.20-0.26 X_{Grs}). The outer garnet rim (<50 μm) locally displays a small decrease in grossular content (0.24-0.22 X_{Grs}). Spessartine content decreases from core to rim (0.10-0.01 X_{Sp}). These variations are interpreted to reflect growth zoning with increasing temperature and pressure. The alternative that the increase in grossular was caused by a change in the phase assemblage (e.g. involving release of CaO via the breakdown of epidote; Menard and Spear, 1994) is considered unlikely for two reasons. First, the change in grossular content is gradual and not abrupt. Second, epidote inclusions are scattered throughout garnet porphyroblasts, with the exception of the extreme garnet rim, and cannot be correlated with the observed changes in grossular content.

Three plagioclase traverses and two hornblende traverses, extending up to 4.0 mm into the matrix away from garnet porphyroblasts (Figure 5-7a and 5-7b), were analysed

for garnet 2 (traverse #2) and garnet 3 (traverse #3a and #3b). Most plagioclase grains show significant zoning from sodic cores to calcic rims. Also, plagioclase grains adjacent to garnet rims have higher anorthite content than grains located further away in the matrix. There is, however, significant heterogeneity between microdomains that appears to reflect variable reequilibration of plagioclase during garnet breakdown.

The first traverse (plagioclase traverse #1; Figures 5-7a and 5-8a) is oriented approximately perpendicular to the main foliation, and is less than 200 μm in length. Plagioclase analysed from embayments within the garnet have $X_{\text{An}}=0.52$ for rims and 0.39 for cores. The anorthite content of plagioclase immediately adjacent to garnet, but not within the garnet breakdown zone, ranges from $X_{\text{An}}=0.31$ -0.63 for rims and $X_{\text{An}}=0.24$ -0.29 for cores.

Plagioclase traverse #2 is oriented perpendicular to the main foliation, and is approximately 400 μm in length (Figures 5-7a and 5-8d). Plagioclase grains analysed from embayments within garnet have $X_{\text{An}}=0.43$ -0.71 for rims and $X_{\text{An}}=0.50$ -0.58 for cores, with rims generally displaying higher anorthite contents than cores. With increasing distance into the matrix, the anorthite content generally decreases, ranging from $X_{\text{An}}=0.47$ -0.53 for rims and $X_{\text{An}}=0.27$ -0.37 for cores.

Two plagioclase traverses, #3a and #3b, both run perpendicular to the main foliation, and are approximately 1 mm and 4.2 mm in length, respectively (Figures 5-7b and 5-8f). Plagioclase grains analysed from within the garnet breakdown zone for traverse #3a range from $X_{\text{An}}=0.30$ -0.53 for rims and $X_{\text{An}}=0.27$ -0.49 for cores. The highest anorthite contents are displayed in the rims of grains located within a garnet

embayment ($<20\ \mu\text{m}$ away from the garnet rim), and likely formed during garnet breakdown. Anorthite contents of plagioclase decrease with increasing distance into the matrix, ranging from $X_{\text{An}}=0.23-0.38$ for rims and $X_{\text{An}}=0.19-0.28$ for cores. The plagioclase located the farthest away from garnet, P155 (rim) and P156 (core), does not display significant zoning, indicating that plagioclase reequilibration during garnet breakdown was minimal at distances greater than 1 mm away from the garnet rim.

Plagioclase traverse #3b displays the same trend as described for #3a and 3b (Figures 5-7b and 5-8l). Plagioclase grains analysed from within the garnet breakdown zone range from $X_{\text{An}}=0.46-0.71$ for rims and $X_{\text{An}}=0.50-0.66$ for cores. Rims generally display higher anorthite contents, with the exception of P249 and P251, which display anomalously high anorthite contents. P249 and P251 are located within two small plagioclase grains immediately adjacent to a large hornblende crystal, which may have been a site affected by late fluids.

Anorthite content decreases with increasing distance from garnet into the matrix. Plagioclase rims of small grains immediately adjacent to large hornblende grains are generally more calcic, similar to that observed within the garnet breakdown zone. The anorthite content in these areas range from $X_{\text{An}}=0.46-0.71$ for rims and $X_{\text{An}}=0.50-0.86$ for cores. The most sodic compositions ($X_{\text{An}}=0.14-0.47$ for rims and $X_{\text{An}}=0.14-0.43$ for cores) are best preserved within the cores of large plagioclase grains. The plagioclase heterogeneity is not considered to reflect whole rock chemical inhomogeneity, as this pattern is consistently observed within all plagioclase traverses for garnet amphibolite. A second possibility, that heterogeneity is associated with systemically changing chemical

compositions throughout prograde metamorphism, is considered unlikely as variations in anorthite compositions directly correlate to textural differences within the rock (i.e. garnet breakdown zone vs. matrix grains). Extremely sodic compositions are interpreted to represent prograde plagioclase compositions that have not reequilibrated during later garnet growth or breakdown.

Two plagioclase inclusions were analysed within garnet 3 (Figures 5-6, 5-8n - p), and best reflect prograde plagioclase compositions. The anorthite content ranges from $X_{An}=0.26-0.32$ for rims and $X_{An}=0.32-0.36$ for cores. Unfortunately, garnet porphyroblasts do not contain any hornblende or biotite inclusions. In order to calculate a temperature, it was assumed that matrix hornblende, which defines the main foliation within the rock, was in equilibrium with the plagioclase inclusions and surrounding garnet. To minimize the effects of later reequilibration, compositions of cores from hornblende grains well removed from the garnet breakdown zone were used. Calculated prograde P-T conditions range from 650 °C/9.6 kbar and 665 °C/9.4 kbar using plagioclase inclusion cores, and 655 °C/9.8 kbar and 640 °C/10.6 kbar using plagioclase inclusion rims (Figure 5-9). The average prograde P-T condition is 650 °C/ 9.8 kbar. As inclusions are positioned fairly close to the garnet rim (< 1mm away), this P-T condition is interpreted to reflect prograde, near-peak metamorphic conditions.

With continued garnet growth, it is assumed that the garnet rim (> 200 µm from the extreme garnet rim) was in equilibrium with plagioclase and hornblende nearby the garnet (within 400 µm), but not texturally associated with the garnet breakdown zone. Two domains, area 1-1 (Figure 5-8c) and area 1-2 (Figure 5-9b), from opposite sides of

garnet 1 were identified as representative of peak metamorphic conditions. These yield P-T conditions of 725 °C/12.1 kbar and 660 °C/ 10.7 kbar, respectively (Figure 5-10). One domain was analysed from garnet 2 (area 2-4; Figure 5-8k), and yields a P-T condition of 665 °C at 10.7 kbar (Figure 5-10). It is important to note that these three calculations are less robust than those calculated using compositions of garnet and adjacent hornblende and plagioclase inclusions. Of these three domains, area 1-1 is not considered to be a reliable calculation as it is so different from the other 2 domains. Also, rocks which experienced temperatures of > 700 °C should show partial melt features in pelites, none of which is observed within samples of the Stonecutter supracrustal unit.

P-T conditions were calculated for garnet breakdown textures from garnet embayments containing anorthite-rich plagioclase adjacent to grossular-poor garnet rims. Four domains were identified from garnet 2 (area 2-1, 2-2, 2-3, 2-5; Figures 5-8f - j), and yield similar P-T conditions of 765 °C/10.0 kbar, 720 °C/10.4 kbar, 735 °C/9.3 kbar, and 770 °C/11.5 kbar (Figure 5-11), respectively. One domain (area 3-1; Figure 5-8m) from garnet 3 yields a P-T condition of 700 °C at 9.7 kbar (Figure 5-11). Garnet breakdown is expected to occur at either relatively low or significantly high P-T conditions, as noted on the phase diagrams (Figure 5-2; Figure 5-4). However, the temperatures and pressures calculated within the garnet breakdown zone are not dissimilar to those calculated for peak conditions. This indicates that the P-T conditions calculated from the garnet breakdown zone do not reflect breakdown conditions.

Thin section BLB97-003a

Five garnet porphyroblasts, and surrounding minerals, were analysed from thin section BLB97-003a (Figures 5-12a and 5-12b). Porphyroblasts range in diameter from 1.0 to 3.0 mm, and most display narrow breakdown regions (100-500 μm in width) consisting of a randomly oriented, fine-grained intergrowth of plagioclase, hornblende, and quartz. The five garnet porphyroblasts display similar compositional profiles. $\text{Fe}/(\text{Fe}+\text{Mg})$ ratios decrease from core to rim (0.87-0.82), whereas grossular content generally increases from core to rim (0.21-0.26 X_{Grs}). The outer garnet rim (<50 μm) locally displays a small increase in $\text{Fe}/(\text{Fe}+\text{Mg})$ and a small decrease in grossular content ($\text{Fe}/(\text{Fe}+\text{Mg})=0.81\text{-}0.85$; $X_{\text{Grs}}=0.27\text{-}0.25$). Spessartine content exhibits either a relatively flat profile, or a slight to moderate decrease from core to rim (0.1-0.01 X_{Sp}). These variations are interpreted to reflect an increase in temperature and pressure with progressive garnet growth.

Three plagioclase traverses (Figures 5-13a and 5-13b), and one hornblende traverse (Figure 5-13a), extending up to 2.2 mm into the matrix from grains adjacent to garnet porphyroblasts, were analysed for garnet 3, 4 and 5 (traverse #3, #4, and #5, respectively). Plagioclase traverse # 3 (Figure 5-13a and 5-14g) is oriented approximately parallel to the main foliation, and is 500 μm in length. The anorthite content for plagioclase grains located within garnet embayments (generally < 50 μm from garnet rim) ranges from $X_{\text{An}}=0.55$ for rims and $X_{\text{An}}=0.20$ for cores. Anorthite contents of matrix plagioclase further away are similar, ranging from $X_{\text{An}}=0.51\text{-}0.55$ for rims and

$X_{An}=0.31-0.38$ for cores, with rims generally displaying higher anorthite contents, and are interpreted to have been reset during garnet breakdown.

Similar to the first traverse, plagioclase traverse #4 (Figure 5-13a and 5-14i) is oriented approximately parallel to the main foliation, and is 500 μm in length. The anorthite content of plagioclase located adjacent to the garnet porphyroblast (generally < 50 μm from garnet rim) is $X_{An}=0.53$ for the rim, and $X_{An}=0.52$ for the core. With increasing distance into the matrix, the X_{An} level decreases, ranging from 0.32-0.48 for rims, and 0.15-0.30 for cores.

Plagioclase traverse #5 is oriented perpendicular to the main foliation, and is 2.2 mm in length (Figure 5-13b and 5-14j). Plagioclase analysed adjacent to garnet, but not texturally associated with garnet breakdown, shows patchy areas of elevated levels of anorthite. Immediately adjacent to the garnet porphyroblast, a small plagioclase grain displays a rim with $X_{An}=0.49$ and a core with $X_{An}=0.51$, and two slightly larger grains have $X_{An}=0.42-0.47$ rims and $X_{An}=0.40-0.51$ cores. These elevated levels of anorthite, although not directly related to new mineral growth, likely reflect resetting during garnet breakdown. With increasing distance into the matrix, the anorthite content generally decreases, ranging from $X_{An}=0.29-0.45$ for rims and $X_{An}=0.30-0.37$ for cores. Two small plagioclase grains (P226 and P240; Figure 5-13b) are anomalously calcic ($X_{An}=0.46-0.50$). Similar to thin section MT98-102, these grains are located immediately adjacent to large hornblende crystals, and are interpreted to have been preferentially reset due to fluid infiltration.

Prograde metamorphic conditions can best be assessed from garnet inclusions. Within thin section BLB97-003a, two plagioclase inclusions are present (garnet 5; Figures 5-13b, 5-14j). The first inclusion (Figure 5-14k) is 30 x 15 μm in size, with $X_{\text{An}}=0.19-0.20$, and shows no significant compositional difference between core and rim. The second inclusion (Figure 5-14l) is closer to the core and much smaller in size (10 μm), resulting in only one spot being analysed ($X_{\text{An}}=0.29$). One hornblende inclusion (Figure 5-14m), approximately 15 x 20 μm in size, was preserved within garnet 5 and is used for all prograde calculations. Plagioclase preserved around this hornblende inclusion is too small (<5 μm in width) to yield a good analysis. Inclusion #1 yields P-T condition of 650 °C/13.3 kbar (Figure 5-15). The second inclusion yields a slightly lower P-T condition of 670 °C/11.4 kbar (Figure 5-15). The average prograde P-T condition is 660 °C/12.4 kbar.

As mentioned above, plagioclase and hornblende inclusions in garnet are very rare and an alternative means of calculating prograde and peak metamorphic conditions must be applied. It has been assumed in many studies that the interior part of the garnet rim (> 50 μm and < 200 μm from the extreme garnet rim) is in equilibrium with plagioclase and hornblende near the garnet (within 600 μm), but not texturally associated with a garnet breakdown zone. Support for this methodology comes from comparison of results with those presented above based on inclusions. Two domains from garnet 3, area 3-1 and area 3-2 (Figures 5-14g - h), are interpreted to represent peak metamorphic conditions (garnet rim with matrix hornblende and plagioclase) and yield P-T conditions of 750 °C/10.0 kbar and 675 °C/9.4 kbar (Figure 5-15), respectively. Area 3-2 is considered to

be the more reliable of the two calculations, because more calcic plagioclase from area 3-1 that yields a higher temperature may reflect later reequilibration associated with garnet breakdown elsewhere in this thin section.

P-T conditions for garnet breakdown are best preserved within garnet embayments containing anorthite-rich plagioclase adjacent to grossular-poor garnet rims. Two domains were used from garnet 1, area 1-1 and area 1-2 (Figures 5-14a - d), which yielded identical P-T conditions of 765 °C/10.5 kbar (Figure 5-16). Although located texturally within a garnet breakdown zone, these garnet compositions are only moderately low in grossular content, and may reflect inhomogeneity during thermal resetting. Two additional domains containing grossular-poor garnet compositions were identified from garnet 2 (area 2-1 and 2-2; Figures 5-14e - f) and yield similar P-T conditions of 730 °C/9.0 kbar and 720 °C/8.4 kbar (Figure 5-16) respectively, the average of which is 725 °C/8.7 kbar. As discussed above, garnet breakdown is expected to occur at either relatively low or significantly high P-T conditions. Similar to thin section MT98-102, these temperatures are higher than what is indicated by the mineral assemblage for pelite schists. This suggests that the P-T conditions calculated from the garnet breakdown zone do not reflect breakdown conditions, but may reflect disequilibrium between hornblende and plagioclase grains.

II. Pelite schist

As discussed above, pelitic schists generally contain the phase assemblage garnet + quartz + plagioclase + biotite + muscovite ± kyanite ± chlorite. Garnet porphyroblasts predominantly display two different textures: (1) unaltered dodecahedral crystals, or (2)

relict embayed crystals that indicate up to 75 % garnet breakdown. Overall, the uniformity of texture with respect to chemical composition suggest that garnet cores and matrix grains may have equilibrated over a thin section scale. This texture represents early, pro-grade to near-peak P-T conditions. The garnet breakdown zone, ranging from < 1 mm to > 250 μm in width, consists of randomly oriented plagioclase, biotite, muscovite, and quartz, and represents garnet breakdown conditions.

Compositional variations of major phases for pelitic samples are presented in order to assess overall variability and to guide selection of mineral compositions that are assumed to have been in equilibrium during garnet growth, and thus used in the P-T calculations.

Chemical composition and P-T results

BLB98-003e

Three garnet porphyroblasts, and surrounding minerals, were analysed from thin section BLB98-003e (Figures 5-17, 5-18, and 5-19). Garnet #2 and #4 are 2 mm and 3 mm in diameter, and display prominent breakdown textures (0.5-1 mm in width) consisting of a fine-grained mixture of randomly oriented biotite, muscovite, plagioclase, and quartz. Garnet #1 is 8 mm in diameter, and exhibits a small breakdown rim (< 200 μm in width). An element distribution map (x-ray map; Figure 5-20), displaying variations in elemental abundances, was produced for garnet 1, and two detailed garnet compositional profiles (garnet 1 and 4; Figure 5-17) were examined to determine the extent of chemical zoning within garnets. In general, both garnet porphyroblasts display similar compositional profiles. Fe/(Fe+Mg) ratios decrease from core to rim (0.90-0.75),

whereas X_{Grs} concentrations generally increase from core to rim ($X_{\text{Grs}}=0.16-0.21$), with a drop in X_{Grs} at the extreme garnet rim and within some fractures internal (Figure 5-18) to the garnet ($X_{\text{Grs}}=0.07$). The concentration of MnO exhibits either a relatively flat profile, or a slight to moderate decrease from core to rim ($X_{\text{Mn}}=0.10-0.01$). The “bell-shaped” MnO profile is typical of growth zoning during metamorphism (Spear, 1993), and along with increasing X_{Grs} and decreasing Fe/(Fe+Mg) from core to rim, suggest growth zoning produced with increasing pressure and temperature. However, the marked decrease of X_{Grs} at the extreme garnet rim and, particularly, the local decrease along fractures internal to garnet porphyroblasts, indicates a second metamorphic event at lower pressures. Along one fracture located within the core of garnet #1, and at the extreme rim of garnet 3, there is a small increase in Fe/(Fe+Mg), associated with the X_{Grs} decrease, which suggests cooling after the second metamorphic event (Figure 5-17).

Three plagioclase/biotite traverses (Figure 5-18) extending from grains immediately adjacent to the garnet porphyroblasts out into the matrix, were analysed to determine the extent of chemical inhomogeneity within the thin section. Two traverses, Pl/Bt traverse #1a and #1b, incorporate garnet breakdown and matrix grains associated with garnet 1. The third traverse (Pl/Bt traverse #4) is associated with garnet 4.

Plagioclase traverse #1a is oriented perpendicular to the main foliation, and is 3 mm in length (Figure 5-18 and 5-21a). The first 200 μm incorporates small, randomly oriented grains of biotite, muscovite, plagioclase and quartz, produced by garnet break down via a simplified reaction (see section 5.3.1) like: $\text{Gnt} + \text{Ms} + \text{H}_2\text{O} = \text{Bt} + \text{Pl} + \text{Qtz}$. Within the garnet breakdown zone ($\sim 200 \mu\text{m}$ in width), plagioclase grains generally

contain higher anorthite component ($X_{An}=0.31-0.40$) than those located within the matrix. Rims of individual plagioclase grains generally contain slightly lower anorthite contents than do cores ($X_{An}=0.31-0.33$ for rims versus $X_{An}=0.38$ for cores). This pattern is the opposite of what is observed elsewhere throughout the rock, and is interpreted to reflect poor data selection (2 out of 3 core analyses had poor totals). At a distance of approximately 1.5-2 mm away from the garnet, plagioclase generally shows little to no zoning. Matrix grains are medium- to coarse-grained, and lie within the main foliation. They also show slight rim to core chemical variation ($0.29-0.24 X_{An}$, respectively), but consistently display lower anorthite contents than that preserved within plagioclase of the garnet breakdown zone.

Plagioclase traverse #1b is oriented parallel to the main foliation, and is 2.0 mm in length (Figure 5-18 and 5-21c). The anorthite content of plagioclase located within the garnet breakdown zone ($< 200 \mu\text{m}$ in width) ranges from $X_{An}=0.29-0.33$ for rims and $X_{An}=0.30-0.31$ for cores, with rim compositions generally exhibiting higher anorthite contents. Matrix plagioclase generally shows lower X_{An} , ranging from 0.23-0.29 (rims) and 0.20-0.29 (cores), with plagioclase rims generally exhibiting higher anorthite contents.

The third traverse, plagioclase traverse #4, is oriented approximately parallel to the main foliation, and is roughly 6.0 mm in length (Figure 5-18 and 5-21h). The chemical variation of anorthite within plagioclase grains is not as pronounced as that described in the above two traverses. The anorthite content of plagioclase associated with the garnet breakdown zone ($< 100 \mu\text{m}$ in width) ranges from $X_{An}=0.26-0.31$ for rims, and

$X_{An}=0.28-0.31$ for cores, whereas within the matrix, the X_{An} ranges from 0.26-0.30 for rims and 0.22-0.28 for cores. The anorthite content is consistently higher in rim compositions for both the garnet breakdown zone and matrix grains.

The most calcic compositions are exhibited in the rims of plagioclase grains within garnet breakdown zones, and in plagioclase associated with fractures internal to garnet that locally displays a marked decrease in grossular content. This decrease in the grossular content of garnet, and associated increase of anorthite content of plagioclase, is interpreted to reflect operation of net transfer reaction #2 during a second metamorphic event at lower pressure.

Biotite grains do not show the same extent of chemical variation as do plagioclase grains (Figure 5-19). Their $Fe/(Fe+Mg)$ ratios range from 0.38-0.44, with biotite located within the garnet breakdown zone generally displaying slightly higher $Fe/(Fe+Mg)$ ratio than those located in the matrix. Fe-Mg exchange is widely considered to be operative at the 550-700 °C temperatures experienced by the Nowyak complex (see below; Spear et al., 1993), and this provides the potential to modify garnet and biotite compositions markedly. This study minimized the potential for exchange by analyzing Fe-Mg minerals only where they are separated by quartz and plagioclase grains. Nevertheless, the highest $Fe/(Fe+Mg)$ ratios should be best preserved within the cores of large biotite grains found within the matrix, and these are the grains most likely to reflect peak temperature conditions of the first metamorphic event.

Given the lack of biotite and plagioclase inclusions within garnet porphyroclasts of this rock, the garnet core is assumed to have been in equilibrium with matrix biotite,

kyanite, and plagioclase grains (refer to section 5.3.2). Thus, early prograde P-T conditions have been estimated by a combination of grossular-rich garnet inner-core compositions, together with anorthite-poor plagioclase and Fe/(Fe+Mg)-rich biotite matrix grains well removed from the breakdown zone. Two domains (Figure 5-21a and b), area 1-1a and area 1-1b, from garnet 1 were identified as best representatives of early prograde conditions, and these record temperatures and pressures of 560 °C/8.9 kbar and 575 °C/9.0 kbar, respectively (Figure 5-22). The average prograde P-T condition recorded in garnet 1 is 570 °C/9.0 kbar.

With continued garnet growth, it is assumed that the garnet inner rim was in equilibrium with plagioclase and biotite closer to the garnet (within 200 µm), but not texturally associated with the garnet breakdown zone. Two domains (Figure 5-21c-e), area 1-2 and area 1-3, from opposite sides of garnet 1 are identified as representative of inner rim conditions. For areas 1-2a and 1-3a, P-T conditions were calculated using the compositions of the inner-rim garnet (> 500 µm from the outer rim) with the core compositions of matrix plagioclase and biotite grains adjacent to the garnet (within 200 µm). For areas 1-2b and 1-3b, P-T conditions were calculated for the inner-rim garnet (~100 µm away from the garnet rim) with the rim compositions of matrix plagioclase and biotite grains. Areas 1-2a and 1-3a yield P-T conditions of 650 °C/11.8 kbar and 675 °C/11.8 kbar, respectively (Figure 5-23). Areas 1-2b and 1-3b yield peak P-T conditions of 750 °C/13.2 kbar and 725 °C/12.7 kbar, respectively (Figure 5-23). As no evidence of partial melting has been observed, these temperatures are higher than reasonable, likely

resulting from mineral compositions not being in equilibrium. The average peak metamorphic condition calculated from areas 1-2a and 1-3a is 660 °C/11.8 kbar.

A marked decrease in X_{Grs} of garnet, observed locally within fractures internal to garnet and at the extreme outer rim (<50 μm) of garnet, is associated with an increase in X_{An} of plagioclase, and is taken to indicate a second, low-pressure, metamorphic event. The extreme rim of garnet 3 (area 3-1; Figure 5-21f and g), and an internal fracture within garnet 1 (area 1-4; Figure 5-21e) display the lowest X_{Grs} values. Together with calcic plagioclase and Fe-rich biotite, these compositions yield P-T conditions of 500 °C/4.2 kbar and 515 °C/4.2 kbar, respectively (Figure 5-24), with an average of 510 °C/4.2 kbar.

MT98-146

Five garnet porphyroblasts, and surrounding minerals, were analysed from thin sections MT98-146A and MT98-146B (Figures 5-25, 5-26, and 5-27). Two porphyroblasts (2.0 mm and 2.4 mm in diameter; garnets 3 and 2, respectively) displayed advanced stages of breakdown textures, consisting of a randomly oriented, fine-grained mixture of biotite, muscovite, plagioclase, and quartz. The other three garnet porphyroblasts (3.0, 4.0, and 7.0 mm in diameter; garnets 6, 4, and 5, respectively) exhibit negligible garnet breakdown. An element distribution map (x-ray map, Figure 5-28), displaying variations in elemental abundances, was produced for garnet 5, and five detailed garnet compositional profiles (garnet 3, 4, 5, 6a, and 6b; Figure 5-25) were examined to determine the extent of chemical zoning within garnets.

Garnet porphyroblasts display similar compositional profiles to that seen in thin section BLB98-003e. Fe/(Fe+Mg) ratios decrease from core to rim (0.86-0.77), whereas

grossular concentrations generally increase from core to rim ($0.14\text{--}0.19 X_{\text{Grs}}$), with a drop in grossular ($0.10 X_{\text{Grs}}$) at the extreme garnet rim and within some fractures internal to the garnet. Spessartine exhibits either a relatively flat profile, or a slight to moderate decrease from core to rim ($0.10\text{--}0.01 X_{\text{Sp}}$). Together with increasing CaO and decreasing Fe/(Fe+Mg) from core to rim, this “bell-shaped” MnO profile suggests growth zoning produced during increasing pressure and temperatures (Spear, 1993). Analogous to thin section BLB97-003e, the sharp decrease of X_{Grs} at the extreme garnet rim and locally against fractures internal to the garnet porphyroblasts is interpreted to result from a second metamorphic event at lower pressures. Also, at the extreme rim of garnet 5, associated with the X_{Grs} decrease there is an increase in Fe/(Fe+Mg), indicating a lower temperature for the second metamorphic event (Figure 5-25).

Three plagioclase traverses, and two biotite traverses (Figures 5-26 and 5-27), extending from grains immediately adjacent to the garnet porphyroblasts out into the matrix, were analysed to determine the extent of chemical inhomogeneity within the thin section. Plagioclase traverse #5 is oriented perpendicular to the main foliation, and is 2.5 mm in length (Figures 5-26 and 5-29f). The first 50 μm traverses small, randomly oriented grains within the garnet breakdown zone. Within this zone, plagioclase grains contain higher anorthite than those located within the matrix ($X_{\text{An}}=0.36$ versus 0.15), although within both locations, plagioclase rims consistently exhibit higher anorthite than cores. Plagioclase rims within the breakdown zone range from $X_{\text{An}}=0.19\text{--}0.36$, whereas cores range from $X_{\text{An}}=0.18\text{--}0.29$. Within the matrix, plagioclase rims range from $X_{\text{An}}=0.19\text{--}0.23$ and cores range from $X_{\text{An}}=0.15\text{--}0.20$.

Traverse #6a is oriented parallel to the main foliation, and is 2.0 mm in length (Figure 5-26 and 5-29i-j). The anorthite content of plagioclase located within the garnet breakdown zone (<200 μm in width) ranges from $X_{\text{An}}=0.21-0.22$ for rims and $X_{\text{An}}=0.21-0.22$ for cores. Matrix plagioclase generally shows lower anorthite, ranging from $X_{\text{An}}=0.12-0.20$ for rims and $X_{\text{An}}=0.18-0.30$ for cores. Although the chemical variation of anorthite within plagioclase grains of traverse 6a is not as apparent as traverse #5, rims generally exhibit higher anorthite contents than cores.

Traverse #6b is oriented perpendicular to the main foliation, and is 6.0 mm in length (Figures 5-26 and 5-29i). The anorthite content of plagioclase associated with the garnet breakdown zone (<50 μm in width) ranges from $X_{\text{An}}=0.30-0.31$ for rims and $X_{\text{An}}=0.21-0.30$ for cores. Matrix plagioclase ranges from $X_{\text{An}}=0.16-0.22$ for rims and $X_{\text{An}}=0.15-0.22$ for cores. The anorthite content is consistently higher within rim compositions for both the garnet breakdown and matrix grains.

The highest anorthite contents are found in the rims of plagioclase grains within garnet breakdown zones, and within plagioclase intimately associated with fractures internal to garnet, both of which locally display a marked decrease in grossular content. This is also observed in other pelite samples (BLB97-003e, MT98-101), suggesting the operation of net transfer reactions during a second metamorphic event at lower pressure.

Biotite grains exhibit $\text{Fe}/(\text{Fe}+\text{Mg})$ ratios ranging from 0.41-0.45, with biotite located within breakdown zones generally displaying a the same, or slightly higher $\text{Fe}/(\text{Fe}+\text{Mg})$ ratio than those located in the matrix (Figure 5-26). As discussed above for other pelite samples, peak temperatures are likely preserved within cores of large biotite

grains within the matrix, whereas biotite rims within garnet breakdown zones likely reequilibrated during the second metamorphic event.

Thin section MT98-146 does not contain biotite or plagioclase inclusions. In order to calculate peak metamorphic conditions, the garnet core is assumed to have been in equilibrium with matrix biotite, kyanite, muscovite and plagioclase grains (refer to section 5.3.2). Early prograde P-T conditions have been estimated by a combination of grossular- and spessartine-rich inner garnet core compositions, together with anorthite-poor plagioclase, Fe/(Fe+Mg)-rich biotite and muscovite matrix grains well removed from the garnet breakdown zone. Two domains, area 5-1 and 6-1, from garnets 5 and 6 are representative of early prograde conditions (Figures 5-29j and i). These record temperatures and pressures of 455 °C/7.1 kbar and 545 °C/8.7 kbar, respectively (Figure 5-30), with an average P-T condition of 500 °C/7.0 kbar.

In order to estimate peak metamorphic conditions of the first metamorphic event, it is assumed that the garnet inner rim (<500 µm from the extreme rim) was in equilibrium with plagioclase, muscovite and biotite nearby the garnet (>300 µm), but not texturally associated with the garnet breakdown zone. Three domains, area 4-1, area 5-2, and area 6-2, from garnets 4, 5 and 6, are representative of peak metamorphic conditions (Figure 5-29d-j). These three areas yield P-T conditions of 600 °C/11.2 kbar, 595 °C/11.4 kbar, and 580 °C/10.2 kbar, respectively (Figure 5-31), with an average peak P-T of 590 °C/10.9 kbar.

Garnet breakdown conditions were retrieved from fractures internal to garnet and from the extreme outer rim (<50µm) of garnet, both of which record low X_{Grs} associated

with calcic plagioclase. Garnets 2 and 5 (area 2-1 and area 5-3; Figure 5-29a, b, g, and h) display low X_{Grs} at their extreme rims, and yield P-T conditions of 425 °C/3.8 kbar and 590 °C/6.2 kbar, respectively (Figure 5-32). At 425 °C and 3.8 kbar, pelitic rocks should contain abundant chlorite (Figure 5-4). However, this thin section contains only a very small amount of chlorite, indicating that the calculated P-T is unreliable. Garnet 6 (Figure 5-29i) displays an increase in Fe/(Fe+Mg) associated with low X_{Grs} at the extreme rim (area 6-3b), which appears to correspond to the lower temperature of the second metamorphic event. Areas 6-3b and 6-3a yield P-T conditions of 650 °C/7.9 kbar and 560 °C/6.0 kbar, respectively (Figure 5-32).

MT98-101

Two garnet porphyroblasts, and surrounding minerals, were analysed from thin section BLB97-003e (Figure 5-33). Measuring 2.0 and 4.5 mm in diameter, both garnet porphyroblasts are wrapped by the main foliation, and exhibit local breakdown zones (<1 mm in width) around rims and along fractures internal to the garnet grains. The breakdown zones consist of a randomly oriented, fine-grained mixture of biotite, muscovite, plagioclase, and quartz. Coarse-grained kyanite, biotite, and muscovite define a strong foliation and occur with plagioclase and quartz in the matrix.

Garnet porphyroblasts exhibit a moderate Fe/(Fe+Mg) decrease from core to rim (0.88-0.80), and slight increase in grossular content from core to rim (0.17-0.20 X_{Grs}). A drop in grossular content is observed at the extreme garnet rim (Garnet 2; <50 µm away from the garnet edge). Spessartine content decreases from core to rim (0.16-0.08 X_{Sp}).

These profiles are consistent with growth zoning produced with increasing pressure and temperature.

As with thin section MT98-146 and BLB97-003e, plagioclase/biotite traverses (Figures 5-34 and 5-35), extending from grains immediately adjacent to the garnet porphyroblasts out into the matrix, were analysed to determine the extent of chemical inhomogeneity within the thin section. Plagioclase traverse #1 is oriented perpendicular to the main foliation, and is 2.6 mm in length (Figures 5-34 and 5-36d). The first 600 μm incorporates the garnet breakdown zone, which consists of randomly oriented grains of muscovite, plagioclase, quartz, and biotite. Within this zone, plagioclase grains are consistently more calcic than matrix grains. Plagioclase within the breakdown zone range from $X_{\text{An}}=0.31-0.40$ for rims and $X_{\text{An}}=0.28-0.32$ for cores, whereas matrix plagioclase are progressively less calcic away from the garnet, ranging from $X_{\text{An}}=0.14-0.25$ for rims and $X_{\text{An}}=0.18-0.22$ for cores.

Plagioclase traverse #2a (Figures 5-34 and 5-36e) is oriented parallel to the main foliation, and is 2.0 mm in length. Within the first 400 μm of the garnet breakdown zone, anorthite content of plagioclase ranges from $X_{\text{An}}=0.30-0.30$ for rims and $X_{\text{An}}=0.28-0.30$ for cores. Matrix plagioclase grains generally range from $X_{\text{An}}=0.20-0.27$ for rims and $X_{\text{An}}=0.21-0.22$ for cores. However, near the end of the traverse, plagioclase contains anomalously high anorthite content, ranging from $X_{\text{An}}=0.27-0.33$. These plagioclase grains exhibit a moderate degree of sericite alteration, and as a result, have not been used in P-T calculations for this sample.

Plagioclase traverse #2b (Figures 5-34 and 5-36g) is oriented perpendicular to the main foliation, and is 900 μm in length. The first 310 μm incorporates the garnet breakdown zone, and plagioclase contents range from $X_{\text{An}}=0.31-0.37$ for rims and $X_{\text{An}}=0.32-0.35$ for cores. This is higher than that observed within plagioclase located in the matrix, where plagioclase contents range from $X_{\text{An}}=0.20-0.23$ for rims and $X_{\text{An}}=0.21-0.22$ for cores.

As with thin sections MT98-146 and BLB97-003e, the highest anorthite contents are exhibited in the rims of plagioclase grains within the garnet breakdown zones, and within plagioclase intimately associated with fractures internal to garnet where it locally displays a marked decrease in grossular content. As discussed for other pelitic samples (BLB97-003e and MT98-146), these compositional changes are interpreted to result from resetting during a second, lower-pressure, metamorphic event.

Biotite grains range in $\text{Fe}/(\text{Fe}+\text{Mg})$ from 0.41-0.51, with biotite in breakdown zones generally displaying similar $\text{Fe}/(\text{Fe}+\text{Mg})$ to matrix biotite (Figure 5-35). An exception is traverse 2a, in which biotite is slightly higher in Fe adjacent to the garnet porphyroblast. The highest $\text{Fe}/(\text{Fe}+\text{Mg})$ is observed within cores of large matrix biotite. In order to minimize the effects of Fe-Mg reequilibration, large biotite grains surrounded by non-ferromagnetic minerals, such as plagioclase and quartz, were selected to reconstruct peak temperatures of the first metamorphic event.

This thin section does not contain any biotite or plagioclase inclusions within the garnet porphyroblasts. Early prograde conditions are calculated using the garnet core composition, combined with matrix plagioclase and biotite well removed from the garnet

breakdown zone. Two domains, area 1-1 and area 2-2 (Figure 5-36c, d, g and i) are representative of early prograde conditions, and record pressure and temperatures of 540°C/10.8 kbar and 535°C/9.9 kbar, respectively (Figure 5-37), with an average prograde P-T condition of 540 °C/10.4 kbar.

Peak metamorphic conditions were calculated by assuming garnet rims were in equilibrium with matrix grains adjacent to the rims, but not within the garnet breakdown zone. Three domains were calculated using the compositions of the inner-rim garnet (> 500 µm from the garnet edge) combined with the core compositions of matrix plagioclase and biotite grains adjacent (within 300 µm) to the garnet. Garnet 1 (area 1-2; Figure 5-36a, b) yields the highest P-T conditions of 690 °C/14.2 kbar (Figure 5-38). This domain may record an anomalously high pressure, as no other domains for either pelitic rocks or garnet amphibolite record pressures above 12.4 kbar. Garnet 2 (area 2-3 and area 2-4; Figure 5-36g, h) yields replicable P-T conditions of 590°C/9.9 kbar and 550°C/8.9 kbar (Figure 5-38).

As discussed for thin sections MT98-146 and BLB98-003e, garnet breakdown zones are interpreted to have formed during a second metamorphic event occurring at lower pressures. They are defined by calcic plagioclase associated with low-grossular garnet preserved locally within fractures internal to the garnet and at the extreme outer rim. One domain that exhibits low grossular garnet (area 2-1; Figure 5-36e, f) yields a P-T condition of 515 °C/6.2 kbar (Figure 5-39).

Summary

Rocks of the Nowyak complex, from the footwall of the Nowyak shear zone, record a complex and variable chemical history. Complex growth zonation during prograde metamorphism with increasing pressure is indicated by the following core to rim compositional differences: decreasing X_{Sp} , decreasing $Fe/(Fe+Mg)$, and increasing X_{Grs} . However, X_{Grs} is markedly lower at the extreme garnet rim and within some fractures internal to garnet within pelites. These changes are interpreted to reflect reequilibration during a later metamorphic event at lower pressure. Individual garnet porphyroblasts within each thin section appear to have preserved different portions of the pressure-temperature path of the first event (M1), as well as the conditions of the second metamorphic event (M2). The following is a summary of the most reliable P-T conditions calculated for the footwall.

Within garnet amphibolites, prograde conditions are best estimated with plagioclase and hornblende inclusions found within garnet porphyroblasts. Only thin section MT98-102 preserved plagioclase inclusions. In order to calculate a temperature, it was assumed that matrix hornblende was in equilibrium with the plagioclase inclusions and surrounding garnet. Thin section MT98-102 yields a P-T of 650 °C/9.8 kbar. Results from thin section BLB97-003a are considered to be more reliable, as it preserves both plagioclase and hornblende inclusions. It yields an average prograde P-T condition of 660 °C/12.4 kbar (Figure 5-11).

Peak metamorphic conditions were calculated by assuming that, with continued garnet growth, the garnet rim (> 200 μm from the extreme garnet rim) was in equilibrium

with matrix grains closer to the garnet (within 400 μm). These matrix grains are far enough removed from the garnet porphyroblast that they did not reequilibrate during garnet breakdown. Thin sections MT98-102 and BLB97-003a yielded "peak" (i.e. maximum) conditions of 665 $^{\circ}\text{C}/10.7$ and 675 $^{\circ}\text{C}/9.4$ kbar, respectively (Figure 5-40). For BLB97-003a, peak conditions were achieved during exhumation.

Breakdown conditions were calculated from garnet embayments containing anorthite-rich plagioclase adjacent to grossular-poor garnet rims. Thin sections MT98-102 and BLB97-003a yield P-T conditions of 700 $^{\circ}\text{C}/9.7$ kbar and 725 $^{\circ}\text{C}/8.7$ kbar, respectively (Figure 5-40), with an average of 710 $^{\circ}\text{C}/9.2$ kbar. The fact that these temperatures are higher than "peak" conditions suggests that these results may be in error, possibly because calcic plagioclase was not in equilibrium with nearby hornblende.

Within pelitic schist, garnet porphyroblasts do not contain biotite or plagioclase inclusions, and prograde P-T conditions were calculated by assuming that the garnet core was in equilibrium with matrix grains well removed from the garnet. Thin sections BLB97-003e, MT98-146, and MT98-101 yield prograde P-T conditions of 570 $^{\circ}\text{C}/9.0$ kbar, 500 $^{\circ}\text{C}/7.0$ kbar, and 540 $^{\circ}\text{C}/10.4$ kbar, respectively. It is not clear whether the variability of P-T calculated conditions reflects a garnet porphyroblast's capacity to preserve a unique portion of the overall P-T path (Figure 5-40), or incorrect choices of "equilibrium" compositions.

Peak conditions are best preserved within larger-sized garnet porphyroblasts, and were calculated by assuming that, with continued garnet growth, garnet rims (> 200 μm from the garnet edge) were in equilibrium with matrix grains nearby garnet (within 400

μm), but not texturally associated with garnet breakdown. Thin sections BLB97-003e, MT98-146, and MT98-101 record peak P-T conditions of 660 °C/11.8 kbar, 590 °C/10.9 kbar, and 590 °C/9.9 kbar, respectively (Figure 5-40).

Breakdown conditions are best preserved within the pelite samples. A marked decrease in X_{Grs} of garnet, locally within fractures internal to garnet and at the extreme outer rim (<50 μm) of garnet, is associated with an increase in X_{An} of plagioclase, and is interpreted to indicate a second, low-pressure, metamorphic event. Estimated P-T conditions range from 510 °C/4.2 kbar for BLB97-003e; 560 °C/6.0 kbar - 650 °C/7.9 kbar for MT98-146; and 515 °C/6.2 kbar for MT98-101. The average value for all domains of all three pelite samples is 565 °C/6.1 kbar (Figure 5-40).

Results from garnet amphibolites and pelite schist plotted on a P-T-t diagram (Figure 5-40) display different, but not dissimilar P-T-t histories. Both display a clockwise P-T-t path, with maximum pressure of 12.4 kbar at 660 °C, and maximum temperature of 675 °C at 9.4 kbar, consistent with garnet growth during crustal thickening to 40 km and subsequent uplift. P-T conditions of a second metamorphic event at lower pressures is better recorded within the pelite schist by higher X_{An} of plagioclase rims and a marked decrease of X_{Grs} at the extreme garnet rims and locally against fractures internal to the garnet porphyroblasts. This second metamorphic event occurred at temperatures and pressures of approximately 565 °C/6.1 kbar. The garnet breakdown zones within garnet amphibolite do not reliably record this second event, although they do preserve slightly lower X_{Grs} garnet rims and higher X_{An} plagioclase rims. The minor resetting, as

compared to the pelite samples, may reflect increased fluid infiltration in pelites due to their higher permeability compared to amphibolites.

5.4 Discussion and Conclusions

Rocks within the Yathkyed Lake greenstone belt predominantly range from greenschist facies in the south (adjacent to the Nowyak complex) to amphibolite facies in the north. Unfortunately, samples collected from the hanging wall immediately north of the Nowyak shear zone were unsuitable for thermometry, though thin section petrography indicates the area experienced greenschist-facies metamorphism. Typical mineral assemblages contain epidote, amphibole, chlorite, and plagioclase reflecting transition of amphibole to greenschist facies: *chlorite + epidote = Al-amphibole* (Spear, 1993).

Temperatures were calculated for 3 hanging wall samples (YD98-3044, IL96-2166, and CR96-0532). YD98-3044, from the northern portion of the Yathkyed Lake greenstone belt, yields a temperature of 745 ± 25 °C corresponding to Relf et al.'s (1998) field observations in the area, and with P-T estimates of 700 °C at 7.5 kbar (Berman et al., 2000).

IL96-2166 and CR96-0532, from the southern portion of the Kaminak Lake greenstone belt approximately 12 km north of the Nowyak shear zone, yielded results of 580 ± 30 °C and 590 ± 40 °C, respectively, indicating that the area experienced amphibolite-facies metamorphism.

Rocks within the Nowyak shear zone are predominantly greenschist-facies, with a typical mineral assemblage of chlorite + quartz + plagioclase $\pm$ calcite $\pm$ actinolite $\pm$ hornblende $\pm$ opaques $\pm$ epidote. The exception is amphibolite enclaves found

sporadically throughout the shear zone, which contain a typical mineral assemblage of hornblende + plagioclase + quartz + chlorite $\pm$ actinolite $\pm$ calcite $\pm$ opaques + epidote. Temperatures calculated for 4 amphibolite samples range from 545 ± 15 °C - 650 ± 20 °C for core calculations and 590 ± 10 - 640 ± 20 °C for rims. As calculations made with rim analyses are considered more robust, the average temperature experienced by the Nowyak shear zone prior to greenschist-facies retrograde metamorphism, as preserved with amphibolite enclaves, is 615 ± 55 °C.

Footwall rocks preserve evidence for two metamorphic events, M1 and M2. In general, garnets display complex growth zonation interpreted to reflect prograde metamorphism, indicated by the following core to rim compositional differences: decreasing X_{Sp} , decreasing Fe/(Fe+Mg), and increasing X_{Grs} . Peak metamorphic conditions (M1) calculated for garnet amphibolites and pelitic rocks from a supracrustal enclave within the Nowyak metagranite are 660 °C/12.4 kbar and 660 °C/11.8 kbar, respectively. The clockwise nature of the calculated P-T-t path is consistent with garnet growth during crustal thickening to depths of 40 km, and subsequent denudation.

Conditions of the second metamorphic event, M2, are best recorded in garnet breakdown zones within pelite samples. These zones display a marked decrease in X_{Grs} of garnet, locally within fractures internal to the garnet and at the extreme outer rim, associated with an increase in X_{An} of adjacent plagioclase. M2 occurred at approximately 565 °C/6.1 kbar.

Discussion of the two metamorphic events, with respect to the timing of deformation and regional metamorphic events, is discussed in chapter 7.

Figure 5-1: Location map for geothermobarometry samples, modified from Relf et al., 1996.

Figure 5-2: Important reactions controlling epidote-amphibolite stability (modified from Spear, 1993). QFM = experiments performed with oxygen fugacity defined by the quartz-fayalite-magnetite buffer. NNO = experiments performed with the oxygen fugacity defined by the nickel-nickel oxide buffer. Ky = kyanite; And = andalusite; Sil = sillimanite; Ep = epidote; An = anorthite; Grt = garnet; Mag = magnetite.

Figure 5.3: Schematic illustrations outlining chronology of metamorphism and deformation events as observed from petrographic and chemical data.

Garnet amphibolite:

- a) S_i is formed and defined by the orientation of quartz, plagioclase, epidote, and hornblende inclusions.
- b) Quartz and plagioclase inclusion trails are parallel and continuous with S_m . S_m envelops garnet porphyroblasts. Garnet growth is interpreted to be synkinematic with respect to S_m .
- c) Pressure shadows develop in response to inhomogeneous deformation.
- d) Development of garnet breakdown zone consisting of randomly oriented plagioclase, hornblende, and quartz adjacent to the garnet porphyroblast.

Pelite schist:

- a) S_i is formed and defined by the orientation of quartz, plagioclase, and biotite inclusions.
- b) Quartz, biotite and plagioclase inclusion trails are parallel and continuous with S_m . S_m envelops garnet porphyroblasts. Garnet growth is interpreted to be synkinematic with respect to S_m .
- c) Garnet porphyroblast either (i) rotated with respect to fabric development, (ii) overgrew a S_i fold, or (iii) the main fabric changed orientation relative to the growing garnet. Pressure shadows develop in response to inhomogeneous deformation.
- d) Development of garnet breakdown zone consisting of randomly oriented plagioclase, biotite, muscovite, and quartz adjacent to the garnet porphyroblast.

Garnet amphibolite

Pelite schist

Figure 5-4: Petrogenetic grid for pelitic schist (modified from Davidson et al., 1990); H_2O and quartz present. Dotted lines = calculated univariant curve; Dashed lines = approximate univariant curve. Mineral abbreviations from Kretz (1983).

Figure 5.5: A plot of $T_{\text{ed-tr}}$ against $T_{\text{ed-rs}}$ indicating a systematically higher temperature with the use of the $T_{\text{ed-tr}}$ equilibria. Footwall and shear zone rocks: solid diamonds are temperatures calculated for 0, 10 and 15 kbars, and open diamonds are temperatures calculated for 5 kbars. Hanging wall rocks: solid diamonds are temperatures calculated for 0, 5, and 15 kbars, and open diamonds are temperatures calculated for 10 kbars.

Hanging wall rocks

135

Shear zone rocks

Footwall Rocks

Figure 5-6: Thin section MT98-102. Compositional zoning profiles for garnet porphyroblasts. $\diamond$ = Fe/Fe+Mg; $\square$ =

Figure 5-7a: Thin section MT98-102. Compositional zoning profiles for plagioclase and hornblende traverses, showing intergrain compositional differences relative to distance away from garnet. For plagioclase: $\diamond = X_{\text{Al}}^{\text{Al}}; \square = X_{\text{Al}}^{\text{Al}}$; $X = X_{\text{Al}}^{\text{Al}}$; $X = X_{\text{Al}}^{\text{Al}}$. For hornblende: $\diamond = \text{Fe/Fe+Mg}; \square = X_{\text{Al}}^{\text{Al}}; X = X_{\text{Al}}^{\text{Al}}$. Shaded symbols indicate core analyses; clear symbols indicate rim analyses.

Figure 5-7b: Thin section MT98-102. Compositional zoning profiles for plagioclase and hornblende traverses, showing intergrain compositional differences relative to distance away from garnet. $\diamond = X_{Aln}$; $\square = X_{Ab}$; $\times = X_{Or}$; $\blacksquare = X_{Orthoclase}$. Shaded symbols indicate core analyses; clear symbols indicate rim analyses.

Figure 5-8 (A - P): Thin section MT98-102. Backscatter electron images for microprobe domains in garnet amphibolite. Abbreviations from Kretz (1983). Black shaded symbols are inner garnet core analysis; grey shaded symbols are garnet rim analysis. PRC = prograde conditions; PC = peak conditions; BC = breakdown conditions.

Area1-2 (PC)
G13
P64
H54
660 °C/10.7 kbar

Area1-1 (PC)
G4
P28
H27
725 °C/12.1 kbar

Area 2-1 (BC)
 G212
 P228
 H213
 765 °C/10.0 kbar

Area 2-2 (BC)
 G211
 P223
 H210
 720 °C/10.4 kbar

Area 2-3 (BC)
 G217
 P229
 H216
 735 °C/9.3 kbar

Area 2-5 (BC)
G197
P213
H202
770 °C/11.5 kbar

Area 2-4 (PC)
G72
P105
H108
665 °C/10.7 kbar

Area 3-1(BC)
G207
P234
H222
700 °C/9.7 kbar

Inc 1c (PRC)

P146

G167

H158

650 °C/ 9.6 kbar

Inc 1r (PRC)

P145

G165

H158

655 °C/ 9.8 kbar

Inc 2c (PRC)

P139

G132

H158

655 °C/ 9.4 kbar

Inc 2r (PRC)

P138

G134

H158

640 °C/ 10.6 kbar

Figure 5-9: Thin section MT98-102. Summary of TWQ results interpreted as representing prograde metamorphic conditions. Solid line = TWQ equilibria (1991); Dashed line = Plagioclase-hornblende equilibria (Holland and Blundy, 1994). PRC = prograde conditions.

Figure 5-10: Thin section MT98-102. Summary of TWQ results interpreted as representing peak metamorphic conditions.. Solid line = TWQ equilibria (1991); Dashed line = Plagioclase-hornblende equilibria (Holland and Blundy, 1994). PC = peak conditions.

Figure 5-11: Thin section MT98-102. Summary of TWQ results. Solid line = TWQ equilibria (1991); Dashed line = Plagioclase-hornblende equilibria (Holland and Blundy, 1994). BC = breakdown conditions. Note: these results are interpreted as representing near-peak conditions, not breakdown conditions (see text for details).

Figure 5-12a: Thin section BLB97-003a. Compositional zoning profiles for garnet porphyroblasts. $\diamond$ = $X_{\text{Fe/Fe+Mg}}$; $\square$ = $X_{\text{Grossular}}$; $\times$ = $X_{\text{Spessartine}}$

Figure 5-12b: Thin section BLB97-003a. Compositional zoning profiles for garnet porphyroblasts. $\diamond$ = Fe/Fe+Mg; $\square$ = $X_{\text{Grossular}}$; $\times$ = $X_{\text{Spessartine}}$

Figure 5-13b: Thin section BLB97-003a. Compositional zoning profiles for plagioclase and hornblende traverses, showing intergrain compositional differences relative to distance away from garnet. For plagioclase: $\diamond = X_{\text{Albite}}$; $\square = X_{\text{Anorthite}}$; $X = X_{\text{Orthoclase}}$. For hornblende: $\diamond = \text{Fe/Fe+Mg}$; $\square = X_{\text{Aluminum}}$; $X = X_{\text{Sodium}}$. Shaded symbols indicate core analyses; clear symbols indicate rim analyses.

Figure 5-14 (A - M): Thin section BLB97-003a. Backscatter electron images for microprobe domains in garnet amphibolite. Abbreviations from Kretz (1983). Black shaded symbols are inner garnet core analysis; grey shaded symbols are garnet rim analysis. PRC = prograde conditions; PC = peak conditions; BC = breakdown conditions.

Area 1-1
G49
P52
H39
765 °C/10.5 kbar

Area 1-2
G43
P57
H41
765 °C/10.5 kbar

BLB97-003a: Garnet 2

155

Area 2-1 (BC)

G68

P65

H76

730 °C/9.0 kbar

Area 2-2 (BC)

G72

P64

H76

720 °C/8.4 kbar

* Low totals; substituted with
near-by homblende analysis (H76)

Area 3-1c (PC)

G84
P106
H108
750 °C/ 10.0 kbar

Area 3-2c (PC)

G84
P104
H110
675 °C/ 9.4 kbar

Area 5-1 (PRC)

G211

P197

H179

650 °C/13.1 kbar

Area 5-2 (PRC)

G201

P198

H179

670 °C/11.5 kbar

Figure 5-15: Thin section BLB97-003a. Summary of TWQ results interpreted as representing prograde and peak metamorphic conditions.. Solid line = TWQ equilibria (1991); Dashed line = Plagioclase-hornblende equilibria (Holland and Blundy, 1994). PRC = prograde conditions; PC = peak conditions.

Figure 5-16: Thin section BLB97-003a. Summary of TWQ results. Solid line = TWQ equilibria (1991); Dashed line = Plagioclase-hornblende equilibria (Holland and Blundy, 1994). BC = breakdown conditions. Note: these results are interpreted as representing near-peak conditions, not breakdown conditions (see text for details).

Figure 5-17: Thin section BLB97-003e. Compositional zoning profiles for garnet porphyroblasts. $\diamond$ = Fe/Fe+Mg; $\square$ = $X_{\text{Grossular}}$; $\times$ = $X_{\text{Spessartine}}$

Figure 5-18: Thin section BLB07-003e. Compositional zoning profiles for plagioclase traverses, showing intergrain compositional differences relative to distance away from garnet. $\diamond = X_{\text{Albite}}$; $\square = X_{\text{Anorthite}}$; $X = X_{\text{orthoclase}}$. Shaded symbols indicate core analyses; clear symbols indicate rim analyses.

Figure 5-19: Thin section BLB97-003e. Compositional zoning profiles for biotite traverses, showing intergrain compositional differences relative to distance away from garnet. $\diamond$ = Fe/Fe+Mg; $\square$ = X_{Aluminum}; X = X_{TiFe/Fe+Mg}. Shaded symbols indicate core analyses; clear symbols indicate rim analyses.

Figure 5-20: Element distribution maps for pelitic schist (BLB97-003e) from the Stonecutter supracrustal unit, with variation in elemental abundance indicated by colour scale increasing from cool blue to hot red tones. Field of view shows a portion of a garnet with adjacent quartzo-feldspathic matrix. Approximately 1.00 mm field of view

Figure 5-21 (A - H): Thin section BLB97-003e. Backscatter electron images for microprobe domains in pelite schist. Abbreviations from Kretz (1983). Black shaded symbols are inner garnet core analysis; grey shaded symbols are garnet rim analysis. PRC = prograde conditions; PC = peak conditions; BC = breakdown conditions.

<u>Area 1-1a (PRC)</u>	<u>Area 1-1b (PRC)</u>
G54	G66
P216	P238
B202	B212
560 °C/8.9 kbar	575 °C/9.0 kbar

Area 1-3a (PC)

G216

P103

B98

675 °C/11.8 kbar

Area 1-3b (PC)

G220

P102

B98

725 °C/12.7 kbar

Area 1-2a (PC)

G201

P202

B184

650 °C/11.8 kbars

Area 1-2b (PC)

G206

P201

B183

750 °C/13.2 kbar

Area 1-4 (BC)

G76

P81

B203

515 °C/4.2 kbar

Area 3-1 (BC)
G135
P131
B127
500 °C/4.2 kbar

BLB97-003e: Garnet 4

Figure 5-22: Thin section BLB97-003e. Summary of TWQ results interpreted as representing prograde metamorphic conditions. Solid line = TWQ equilibria (1991). PRC = prograde conditions.

Figure 5-23: Thin section BLB97-003e. Summary of TWQ results interpreted as representing peak metamorphic conditions. Solid line = TWQ equilibria (1991). PC = peak conditions.

Figure 5-24: Thin section BLB97-003e. Summary of TWQ results interpreted as representing breakdown conditions. Solid line = TWQ equilibria (1991). BC = breakdown conditions.

Figure 5-25: Thin section MT98-146. Compositional zoning profiles for garnet porphyroblasts. $\diamond$ = Fe/Fe+Mg; $\square$ = $X_{\text{Grossular}}$; $\times$ = $X_{\text{Spessartine}}$.

Figure 5-27: Thin section MT98-146. Compositional zoning profiles for biotite traverses, showing intergrain compositional differences relative to distance away from garnet. $\diamond$ = Fe/Fe+Mg; $\square$ = X_{TiFe}/Fe+Mg; $\times$ = X_{Aluminum}. Shaded symbols indicate core analyses; clear symbols indicate rim analyses.

Figure 5-28: Element distribution maps for pelitic schist (MT98-146) from the Stonecutter supracrustal unit, with variation in elemental abundance indicated by colour scale increasing from cool blue to hot red tones. Field of view shows a portion of a garnet with adjacent quartzo-feldspathic matrix. Matrix grains are either a blue or grey colour. Approximately 1.00 mm field of view.

Figure 5-29 (A - J): Thin section Mt98-146. Backscatter electron images for microprobe domains in pelite schist. Abbreviations from Kretz (1983). Black shaded symbols are inner garnet core analysis; grey shaded symbols are garnet rim analysis. PRC = prograde conditions; PC = peak conditions; BC = breakdown conditions.

Area 2-1 (BC)
G21
P23
B25
M153
425 °C/3.8 kbar

Area 4-1 (PC)
 G72
 P91
 B94
 M92
 600 °C/11.2 kbar

MT96-146A: Garnet 5

181

Figure 5-30: Thin section MT98-146. Summary of TWQ results interpreted as representing peak metamorphic conditions. Solid line = TWQ equilibria (1991). PC = peak conditions.

Figure 5-31: Thin section MT98-146. Summary of TWQ results interpreted as representing prograde metamorphic conditions. Solid line = TWQ equilibria (1991). PRC = prograde conditions.

Figure 5-32: Thin section MT98-146. Summary of TWQ results interpreted as representing breakdown conditions. Solid line = TWQ equilibria (1991). BC = breakdown conditions.

Figure 5-33: Thin section MT98-101. Compositional zoning profiles for garnet porphyroblasts. $\diamond$ = $Fe/Fe+Mg$; $\square$ = $X_{Grossular}$; $X = X_{Spyessartine}$.

Figure 5-35: Thin section MT98-101. Compositional zoning profiles for biotite traverses, showing intergrain compositional differences relative to distance away from garnet. $\diamond$ = Fe/Fe+Mg; $\square$ = X_{Aluminum}; X = X_{TiFe/(Fe+Mg)}. Shaded symbols indicate core analyses; clear symbols indicate rim analyses.

Figure 5-36 (A - I): Thin section MT98-101. Backscatter electron images for microprobe domains in pelite schist. Abbreviations from Kretz (1983). Black shaded symbols are inner garnet core analysis; grey shaded symbols are garnet rim analysis. PRC = prograde conditions; PC = peak conditions; BC = breakdown conditions.

Area 1-2 (PC)
 G147
 P166
 M30
 B163
 690 °C/14.2 kbar

MT98-101: Garnet 1

191

Area 1-1 (PRC)
G10
P174
M30
B167
540 °C/10.8 kbar

Area2-1 (BC)
 G172
 P179
 B172
 M72
 515 °C/6.2 kbar

Area 2-3 (PRC)

G169
P181
B169
M104
590 °C/9.9 kbar

Area 2-4 (PC)

G169
P197
B187
M104
550 °C/8.9 kbar

Area 2-2 (PC)

G55
P187
B179
M104
535 °C/9.9 kbar

Figure 5-37: Thin section MT98-101. Summary of TWQ results interpreted as representing prograde metamorphic conditions. Solid line = TWQ equilibria (1991). PRC = prograde conditions.

Figure 5-38: Thin section MT98-101. Summary of TWQ results interpreted as representing peak metamorphic conditions. Solid line = TWQ equilibria (1991). PC = peak conditions.

Figure 5-39: Thin section MT98-101. Summary of TWQ results interpreted as representing breakdown conditions. Solid line = TWQ equilibria (1991). BC = breakdown conditions.

Figure 5-40: Summary of prograde, peak, and breakdown conditions for garnet amphibolite and pelitic schist (Stonecutter supracrustal unit). Prograde P-T path for the Nowyak complex. Black = garnet amphibolite; Grey = pelitic schist; PRC = prograde conditions; PC = peak conditions; BC = breakdown conditions.

PRC Prograde conditions

PC Peak conditions

BC Breakdown conditions
(2nd metamorphic event)

Pelite schist

Garnet amphibolite

Prograde conditions

Peak conditions

Plate 5-1: Thin section of low-grade amphibolite, MT98-155. Subhedral to euhedral plagioclase, quartz, and hornblende phenocrysts within a fine-grained matrix of hornblende, quartz, and plagioclase. Crossed polars, 4.8 mm field of view. Qtz = quartz; Pl = plagioclase.

Qtz

Pl

Plate 5-3: Thin section of metagranite, IL96-2066A. Myrmekitic texture displaying vermicular quartz intergrowing with plagioclase and adjacent potassium feldspar. Crossed polars, 2.4 mm field of view. Qtz = quartz; Pl = plagioclase; Mc = microcline.

Qtz

Mc

Pl

Plate 5-2: Thin section of metagranite, IL96-2260B. Plagioclase inclusion within coarse-grained microcline grain. Crossed polars, 2.4 mm field of view. Qtz = quartz; Pl = plagioclase; Mc = microcline.

Pl

Mc

Plate 5-4: Thin section of garnet amphibolite, BLB97-003f. Syn deformation garnet growth is indicated by: (1) the matrix foliation wraps around garnet porphyroblast, and (2) plagioclase and quartz inclusion trails parallel matrix foliation. Crossed polars, 1.2 mm field of view.

Plate 5-5: Thin section of garnet amphibolite, BLB97-003f. Syndeformation garnet growth is indicated by plagioclase and quartz inclusion trails, which are parallel and continuous with the matrix foliation. Crossed polars, 1.2 mm field of view.

Plate 5-6: Thin section of garnet amphibolite, BLB97-003f. Biotite grains lie at a high angle to the main foliation. Crossed polars, 2.4 mm field of view.

Plate 5-7: Thin section of garnet amphibolite, BLB-1168. Skeletal garnet porphyroblast contains large inclusions of plagioclase and quartz. Crossed polars, 1.2 mm field of view.

Plate 5-8: Thin section of garnet amphibolite, MT98-102. Garnet porphyroblast is surrounded by coronae of plagioclase and hornblende. Crossed polars, 2.4 mm field of view.

Plate 5-9: Thin section of garnet amphibolite, MT98-102. Plagioclase and quartz inclusions within coarse-grained hornblende grain. Hornblende embayments consist predominantly of plagioclase and quartz. Crossed polars, 2.4 mm field of view.

Plate 5-10: Thin section of pelite schist, MT98-146. Crenulation cleavage (S_{m+1}) is defined by alignment of phyllosilicates. Crossed polars, 1.2 mm field of view.

Plate 5-11: Thin section of pelite schist, MT98-146. Plagioclase and quartz inclusions trails are parallel and continuous with the matrix foliation, which envelopes the garnet porphyroblast, indicating syn-deformation garnet growth. Crossed polars, 2.4 mm field of view.

Plate 5-12: Thin section of pelite schist, MT98-146. Curved inclusion trails of plagioclase and quartz within the garnet porphyroblast, interpreted to represent syn-deformation garnet growth. Crossed polars, 2.4 mm field of view.

Plate 5-13: Thin section of pelite schist, MT98-101. Garnet porphyroblast is rimmed by a randomly oriented, fine-grained mixture of biotite, plagioclase, and quartz. Crossed polars, 2.4 mm field of view.

Plate 5-14: Thin section of pelite schist, MT98-101. Garnet porphyroblast is rimmed by a randomly oriented, fine-grained mixture of biotite, plagioclase, and quartz. $\frac{1}{4}$ of garnet is in the field of view. Crossed polars, 2.4 mm field of view.

Table 5-1: Summary of hornblende-plagioclase thermometry calculated for hanging wall and shear zone samples. From Holland and Blundy, 1994. 207

Hanging wall rocks

YD98-3044	X _{As}	T (C)	X _{As}	T (C)	CR96-0532	X _{As}	T (C)	X _{As}	T (C)
area 1c	0.83	747	area 1r	0.72 728	area 1c	0.30	595	area 1r	0.27 595
H12, P32			H11, P31		H24, P26			H23, P25	
area 2c	0.84	769	area 2r	0.80 758	area 2c	0.26	586	area 2r	0.27 586
H8, P40			H7, P39		H14, P15			H13, P16	
area 3c	0.83	739	area 3r	0.81 740	area 3c	0.30	620	area 3r	0.28 611
H6, P38			H5, P37		H10, P2			H9, P1	
area 4c	0.82	730	area 4r	0.73 750	area 4c	0.29	547	area 4r	0.28 577
H4, P36			H3, P35		H11, P18			H12, P17	
average	745 +/- 25	C		745 +/- 15 C	average	585 +/- 35	C		590 +/- 30 C

IL96-2166	X _{As}	T (C)	X _{As}	T (C)
area 1c	0.33	609	area 1r	0.32 568
H24, P26			H23, P25	
area 2c	0.30	566	area 2r	0.31 562
H14, P15			H13, P16	
area 3c	0.30	589	area 3r	0.30 604
H10, P2			H9, P1	
area 4c	0.24	560	area 4r	0.28 575
H11, P18			H12, P17	
average	580 +/- 30	C		580 +/- 25 C

Shear zone rocks

MT98-157	X _{As}	T (C)	X _{As}	T (C)	MT98-137	X _{As}	T (C)	X _{As}	T (C)
area 1c	0.31	641	area 1r	0.31 640	area 1c	0.25	562	area 1r	0.32 575
H12, P25			H46, P40		H12, P25			H11, P24	
area 2c	0.33	665	area 2r	0.29 643	area 2c	0.27	556	area 2r	0.63 626
H11, P24			H45, P39		H48, P35			H47, P36	
area 3c	0.40	657	area 3r	0.29 622	area 3c	0.27	525	area 3r	0.42 613
H48, P36			H44, P42		H45, P39			H46, P40	
area 4c	0.34	627	area 4r	0.36 647	area 4c	0.22	541	area 4r	0.43 614
H47, P36			H43, P41		H43, P41			H44, P42	
average	650 +/- 25 C		640 +/- 20 C		average	545 +/- 15 C		610 +/- 35 C	

MT98-129	X _{As}	T (C)	X _{As}	T (C)	MT98-135	X _{As}	T (C)	X _{As}	T (C)
area 1c	0.27	585	area 1r	0.28 596	area 1c	0.25	567	area 1r	0.40 633
H2, P17			H1, P16		H16, P2			H15, P1	
area 2c	0.28	612	area 2r	0.26 595	area 2c	0.29	590	area 2r	0.36 605
H4, P14			H3, P13		H14, P6			H13, P5	
area 3c	0.34	623	area 3r	0.28 596	area 3c	0.24	574	area 3r	0.39 648
H32, P40			H31, P39		H44, P42			H43, P40	
area 4c	0.29	575	area 4r	0.26 580	area 4c	0.24	558	area 4r	0.35 591
H28, P19			H28, P18		H46, P39			H45, P38	
average	600 +/- 25 C		590 +/- 10 C		average	570 +/- 20 C		620 +/- 30	

Table 5-2: Summary of thermobarometry results for garnet amphibolite and pelitic schist.
From Berman, 1993.

Footwall Rocks

Garnet amphibolite

MT98-102

PROGRADE	T (C)	P (kbars)	PEAK	T (C)	P (kbars)	BREAKDOWN	T (C)	P (kbars)
Inc 1c	650	9.6	area 1-1	725	12.1	area 2-1	765	10.0
P146,G167,H158			P28,G4,H27			P228,G212,H213		
Inc 1r	656	9.8	area 1-2	660	10.7	area 2-2	720	10.4
P145,G165,H158			P64,G13,H54			P223,G211,H213		
Inc 2c	655	9.4	area 2-4	665	10.7	area 2-3	735	9.3
P139,G132,H158			P105,G72,H108			P229,G217,H216		
Inc 2r	640	10.6				area 2-5	770	11.5
P138,G134,H158						P213,G197,H216		

BL897-003a

PROGRADE	T (C)	P (kbars)	PEAK	T (C)	P (kbars)	BREAKDOWN	T (C)	P (kbars)
Inc 1	655	13.3	area 3-1	750	10.0	area 1-1	765	10.5
P195,G211,H179			P106,G84,H108			P52,G49,H39		
Inc 2	670	11.5	area 3-1	675	9.4	area 1-2	765	10.5
P198,G201,H179			P104,G84,H110			P57,G43,H41		
						area 2-1	730	9.0
						P65,G68,H76		
						area 2-2	720	8.4
						P64,G72,H76		

Pelite

MT98-146

PROGRADE	T (C)	P (kbars)	PEAK	T (C)	P (kbars)	BREAKDOWN	T (C)	P (kbars)
area 5-1	435	7.1	area 5-2	595	11.4	area 2-1	425	3.8
G114,P224			G107,P216			G21,P23		
B223,M154			B215,M154			B25,M153		
area 6-1	545	8.7	area 4-1	600	11.2	area 5-3	590	6.2
G231,P289			G72,P91			G175,P166		
B233,M124			B94,M92			B169,M153		
			area 6-2	580	10.2	area 6-3a	560	6.0
			G269,P258			G249,P234		
			B233,M124			B240,M153		
						area 6-3b	650	7.9
						G248,P234		
						B241,M154		

Table S-2 (Continued): Summary of thermobarometry results for garnet amphibolite and pelitic schist.
From Berman, 1993.

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Pelite

BLB97-003c

PROGRADE	T (C)	P (kbars)	PEAK	T (C)	P (kbars)	BREAKDOWN	T (C)	P (kbars)
area 1-1a	560	8.9	area 1-2a	650	11.8	area 1-4	515	4.2
G54,P216,B202			G201,P202,B184			G76,P81,B203		
area 1-1b	575	9.0	area 1-2b	750	13.2	area 3-1	500	4.2
G66,P238,B212			G206,P201,B183			G135,P131,B127		
			area 1-3a	675	11.8			
			G216,P103,B98					
			area 1-3b	725	12.7			
			G220,P102,B98					

MT98-101

PROGRADE	T (C)	P (kbars)	PEAK	T (C)	P (kbars)	BREAKDOWN	T (C)	P (kbars)
area 1-1	540	10.8	area 1-2	690	14.2	area 2-1	515	6.2
G10,P174			G147,P166			G172,P179		
M30,B167			B163,M30			B172,M72		
area 2-2	535	9.9	area 2-3	590	9.9			
G55,P187			G169,P181					
B179,M104			B169,M104					
			area 2-4	550	8.9			
			G169,P197					
			B187,M104					

CHAPTER SIX: PRELIMINARY ^{40}Ar - ^{39}Ar AND U/Pb GEOCHRONOLOGY OF THE NOWYAK COMPLEX

FIGURES:

Figure 6-1: Location map for ^{40}Ar - ^{39}Ar and SHRIMP geochronology samples

Figure 6-2(a-q): ^{40}Ar - ^{39}Ar age spectra for hornblende, biotite, and muscovite

Figure 6-3(a-v): Backscatter and cathodoluminescence SEM images of analysed zircon grains

Figure 6-4(a-d): Correlation graphs

Figure 6-5: Concordia diagram

TABLES:

Table 6-1: Summary of the ^{40}Ar - ^{39}Ar thermochronological data

Table 6-2: U-Pb analytical data from the Nowyak complex

COMPLEX

6.1 Introduction

^{40}Ar - ^{39}Ar and SHRIMP (Sensitive High Resolution Ion Microprobe) geochronology were utilized in this study in an attempt to (1) help constrain the timing of movement of the Nowyak shear zone; (2) elucidate the cooling history of the Nowyak complex; and (3) resolve complex timing relationships between peak metamorphism and tectonic exhumation of the complex.

6.2 Previous Work

The core of the Kaminak Lake greenstone belt preserves U-Pb Archean ages ranging from ca. 2600 - 2650 Ma (Davis et al., 2000), and ^{40}Ar - ^{39}Ar argon (hornblende) ages ranging from 2623 - 2660 Ma (Sandeman, in press, 2001). Within the northern part of the Yathkyed Lake greenstone belt, K-Ar hornblende ages obtained within the hanging wall of the Tyrrell shear zone indicate Paleoproterozoic cooling at ca. 2430-2485 Ma (Eade, 1986). The southern part of the Yathkyed belt, however, in large part lacks K-Ar and ^{40}Ar - ^{39}Ar ages; thus it is uncertain whether it experienced the same Paleoproterozoic event. Rocks exposed in a north-south corridor between the northern edge of the Kaminak belt and the southern edge of the Yathkyed belt preserve Proterozoic ^{40}Ar - ^{39}Ar hornblende, muscovite, and biotite plateau ages ranging from ca. 1713 to 1795 Ma, interpreted to indicate Paleoproterozoic tectonothermal activity at temperatures above 500 °C Ma (Sandeman, in press, 2001). ^{40}Ar - ^{39}Ar biotite plateau ages for the Yathkyed Lake greenstone belt and the Kaminak Lake greenstone belt range from ca. 2084 - 1784 Ma,

and are interpreted to reflect Paleoproterozoic resetting of biotite systematics (Sandeman, in press, 2001). Hornblende does not display similar resetting at this time, indicating that temperatures were above 280 °C, but below 500 °C.

Early isotope studies for four whole rock samples from the Nowyak metagranite yielded a Rb-Sr isochron age of 2404 ± 184 Ma, interpreted as the age of crystallization (Wanless and Eade, 1975). This age was supported by three $^{207}\text{Pb}/^{206}\text{Pb}$ ages, interpreted to be crystallization ages, of 2335 Ma (zircon), 2285 Ma (zircon), and 2253 Ma (titanite; Wanless and Eade, 1975).

Recent dating of the Nowyak metagranite has yielded an Neoarchean crystallization age of 2643 ± 3 Ma; the upper intercept of the 7 point discordia chord is defined by 4 multigrain titanite (T1,T2,T3,T4) and 3 multigrain zircon (Z3-A, Z2, Z5) fractions (MacLachlan et al., in preparation, 2001). Fractions Z4, Z3, Z1 fell slightly to the right of the discordia line, interpreted as an indication of minor inheritance (MacLachlan et al., in preparation, 2001). MacLachlan et al. note that the sample experienced significant recrystallization, and interpret this to indicate that titanite U/Pb systematics remained undisturbed during the Proterozoic (MacLachlan et al., in preparation, 2001). Deformation is therefore interpreted to have occurred during or shortly after crystallization (MacLachlan et al., in preparation, 2001), implying that the lineation and foliation observed within the Nowyak metagranite is Archean in age.

Berman et al. (personal communication, 2000) obtained SHRIMP II ages for 4 monazite grains (M1, M2, M22, and M24) from a biotite-muscovite-garnet pelitic schist within the Stonecutter supracrustal unit. M1 is located proximal to a zone of garnet

breakdown and is surrounded by a biotite grain that is parallel to the main foliation. It yielded an age of 1813 ± 8 Ma (1σ). M21 is located within a garnet breakdown zone, and yielded an age of 1807 ± 18 Ma (1σ). M22 is located within a recrystallized plagioclase grain adjacent to foliation-parallel biotite, and yielded an age of 1830 ± 12 Ma (1σ). M24 is interstitial with respect to the main fabric, and thus interpreted by Berman (personal communication, 2000) as synchronous with the foliation; M24 yielded an age of 1826 ± 11 Ma (1σ). Berman interpreted monazite growth at ca. 1820 Ma to be related to intrusion of 1.83 Ga Hudsonian granites (Peterson, 2000), but could not discriminate whether the high-P metamorphism occurred at this time or earlier.

6.3 ^{40}Ar - ^{39}Ar geochronology

^{40}Ar - ^{39}Ar geochronology is a variant of the K/Ar isotope method of isotope dating, in which the radioactive isotope ^{40}K decays to $^{40}\text{Ar}^*$ (radiogenic argon). The ^{40}Ar - ^{39}Ar method is different than K-Ar in that step-heating analysis, used to determine variations in the $^{40}\text{Ar}^*/^{39}\text{Ar}_\text{K}$ ratio measured on successively released gas fractions, yield an Ar release pattern that will give critical information on the argon retention and cooling history of the analyzed mineral (e.g. whether the system remained closed to subsequent thermal events). The integrated ^{40}Ar - ^{39}Ar age will be the equivalent of a K-Ar age.

Age determinations using the ^{40}Ar - ^{39}Ar method require that the sample be irradiated in a nuclear reactor to cause a small proportion of ^{39}K atoms to transform to ^{39}Ar atoms by nuclear interaction. The $^{40}\text{Ar}^*/^{39}\text{Ar}_\text{K}$ ratio is subsequently determined, where $^{40}\text{Ar}^*$ is the radiogenic argon formed by in-situ decay of ^{40}K in the rock, and $^{39}\text{Ar}_\text{K}$ is the ^{39}Ar produced by irradiation of ^{39}K . As individual nuclear reactors use different

definitions of energy to discriminate between fast and slow neutrons, a flux monitor is used. Irradiation of monitor minerals Hb3gr and/or PP-20 (K-Ar age of 1072 Ma; Roddick, 1983), in known geometric relation to the unknown samples, will allow for the calculation of the J-value, a parameter that accurately reflects the integrated neutron flux and thus the proportion of ^{39}Ar produced (McDougall and Harrison, 1999).

The $^{40}\text{Ar}^*/^{39}\text{Ar}_K$ ratio is proportional to the $^{40}\text{Ar}^*/^{40}\text{Ar}$ ratio in the sample, and thus is also proportional to age. Comparison of measured $^{40}\text{Ar}^*/^{39}\text{Ar}_K$ ratios with those of the standard allows the age of the unknown to be calculated (McDougall and Harrison, 1999).

6.3.1 Analytical methods

^{40}Ar - ^{39}Ar geochronology was completed at the Geological Survey of Canada (GSC), Ottawa. For each sample, care was taken to ensure the collection of fresh samples, free of fractures and alteration. Weathered surfaces were initially trimmed in the field and subsequently quartz-blasted and carefully washed to ensure that only fresh rock remained prior to crushing. The samples were crushed and sieved to 300 to 150 μm , and fractions were repeatedly washed in doubly-distilled water, in order to produce a uniform grain size suitable for laser heating. Approximately 15 - 20 grains of biotite and muscovite, and 40 - 50 grains of hornblende were hand picked under a binocular microscope. Care was taken to ensure that the grains were as free of inclusions and internal defects as possible. Grains were loaded into aluminum foil packets and along with symmetrically spaced flux monitors, irradiated in McMaster University's nuclear reactor for ~80 hours, with a subsequent decay time of approximately 4 months. Samples

were divided into 2 or 3 single-grain aliquots (2 to 5 aliquots for hornblende) and loaded into individual holes in a copper planchet, and step-heated individually in an ultrahigh vacuum (UHV) system using a temperature calibrated, CO₂ laser system. Extracted argon was purified and analyzed in a mass spectrometry for relative abundances of ⁴⁰Ar, ³⁹Ar, ³⁷Ar, and ³⁶Ar.

Conventional laser step-heating analysis was used to determine variations in the ⁴⁰Ar*/³⁹Ar_K ratios measured on successively released gas fractions. In general, ⁴⁰Ar-³⁹Ar data are interpreted by plotting the apparent ⁴⁰Ar*/³⁹Ar_K age for each step against the cumulative proportion of argon released, termed an age-spectrum diagram. Properly interpreted, the age spectrum yields an Ar release pattern that gives critical information about the argon retentivity and cooling history of the analyzed mineral. The simplest age spectrum is represented by a series of contiguous gas steps that yield ages that overlap within error. A flat Ar release pattern is called a plateau, and will indicate whether the sample has remained a closed system (e.g. has neither gained nor lost parent or daughter isotopes since crystallization). If the mineral has not remained a closed system (e.g., it may have been thermally disturbed), it may either lose some of its radiogenic argon or incorporate excess argon. Consequently, the age spectra will diverge from its plateau shape. In some cases, an estimate of the age of the thermal event that affected the sample may be derived from the apparent age given by the initially released argon (McDougall and Harrison, 1999).

In this study, data interpretation was predominantly based on the integration of the plateau portions of gas release spectrum, in addition to the total-gas integrated ages.

Plateaux for most samples have been selected on the basis of 3 consecutive gas-release steps, representing >50% of gas released, and typically overlapping, or nearly overlapping in error. "Pseudo-plateaux" have been defined for samples that do not meet the above conditions. For the majority of pseudo-plateaux, the calculated ages most likely corresponds to a meaningful geological event, as discussed below. Plateaux for hornblende analyses have also been selected on the basis of contiguous steps having consistent Ca/K ratios. All reported errors are 1σ .

6.3.2 Results

For all sample locations, refer to Figure 6.1; data are presented in Table 6.1.

Hanging wall rocks

Kaminak Lake greenstone belt

Two low-grade amphibolites, CR96-0532 and IL96-2166, were sampled from within the Kaminak Lake greenstone belt, approximately 12 km NE of the Nowyak complex (Figure 6-1). Both samples comprise of fine- to medium-grained hornblende, actinolite, plagioclase, and quartz. Hornblende generally occurs as euhedral to subhedral grains and defines the main foliation. In sample CR96-0532, some amphibole grains consist of actinolite cores surrounded by hornblende rims, so care was taken to ensure that the grains chosen for analysis were predominantly hornblende in composition. CR96-0532 yielded a total-gas integrated age of 1692 ± 12 Ma. Two replicate aliquots of hornblende, consisting of 5 and 8 steps, respectively, resulted in relatively flat, reproducible spectra (Figure 6-2a). The combined age of the plateau portions of the two aliquots is 1769 ± 12 Ma, consisting of 10 steps and 83% of the ^{39}Ar released. Small

fractions of gas with apparent younger ages at higher power (temperature) were excluded from the plateau age, and are interpreted to represent diffusive loss of Ar related to a later thermal disturbance.

IL96-2166 yields a total-gas integrated age of 1735 ± 11 Ma. Three aliquots of hornblende were analysed, all of which yield variability in ^{40}Ar - ^{39}Ar age among the steps. Aliquot 1 yields a convex-down spectrum, displaying anomalously low age fractions at the beginning and end of the gas-release spectra, possibly due to impurities. Aliquot 2 is less erratic, displaying Ar-loss in the first three low-power steps. Aliquot 3 displays Ar-loss in all 4 steps. Excluding low apparent-age gas fractions, the combined age of the plateau portions comprise 66% of the total gas evolved, and yield an age of 1774 ± 12 Ma (Figure 6-2b).

Yathkyed Lake greenstone belt

CR96-1302 is an amphibolite sampled approximately 5 km NW of the Nowyak complex (Figure 6-1) and comprised of randomly oriented, coarse-grained (up to 2 cm in length) hornblende (~ 60%) and actinolite (~ 30%). Internal fractures contained fine-grained, randomly oriented, recrystallized quartz and secondary calcite veins. It yields a total-gas integrated age of 2901 ± 16 Ma. Two aliquots yield similar spectra, characterized by small saddles near the high-power end of the patterns. The saddles are interpreted to represent "true" cooling ages whereas the remainder of the steps represent gas contaminated by excess argon (Sandeman, in press, 2001), possibly related to the nearby intrusion of the "yellow-granite" pluton. Using 12.2 % of the total ^{39}Ar released by two aliquots, the saddles yield a hornblende pseudo-plateau age of 2670 ± 16 Ma

(Figure 6-2c), interpreted to represent a maximum age. This age is not considered to be robust, as it utilizes less than 50% of total argon released, thereby failing to meet the criterion that defines a plateau.

Sample BH98-9059 comes from the northern part of the greenstone belt, within the upper tectonostratigraphic unit (Figure 6-1). It is a medium-grained, garnet amphibolite that occurs as large rafts within a gneissic tonalite (Sandeman, personal communication, 2001). Sample BH98-9059 yielded a total-gas integrated age (hornblende) of 2493 ± 14 Ma. Three aliquots, each consisting of 4 to 8 steps, resulted in irregular gas release patterns. Aliquot 1 shows a convex-down age spectra, with Ar-loss at the beginning and end of the gas-release spectrum. Aliquot 2 displays low-power steps with older ages, which are interpreted to be the result of excess Ar. Aliquot 3 displays low apparent-age gas fractions for high-power steps. Excluding all aliquots with low apparent ages and steps with significantly older apparent ages, a plateau age of 2460 ± 14 Ma (Figure 6-2d) has been calculated using 78% of total gas evolved. It is identical, within error, to the inverse isotope correlation age (2459 ± 14 Ma; MSWD = 0.7), interpreted by Sandeman (2001) as representing a robust metamorphic cooling age of the hornblende.

Biotite from this sample gives a significantly younger total-gas integrated age of 1768 ± 11 Ma. Two aliquots, consisting of 10 and 11 steps each, yield similar age spectra. Both display a gradual increase in apparent age with laser power, characteristic of diffusive loss of Ar at a later time. Excluding steps with low apparent ages, a plateau age of 1785 ± 11 Ma (Figure 6-2m) has been calculated using 63% of the total gas

evolved. The plateau age is interpreted to give a minimum age, and may imply that the biotite has undergone a later thermal event that partially reset the ^{40}Ar - ^{39}Ar systematics. Utilizing the same steps used in the plateau, the age is identical, within error, to the inverse isotope correlation age (1785 ± 11 Ma; MSWD = 9.8), and is interpreted to represent a metamorphic cooling age (Sandeman, in press, 2001).

Sample AM98-7116A is also located within the upper tectonostratigraphic unit of the Yathkyed Lake greenstone belt (Figure 6-1). It is a medium-grained, locally garnet-bearing amphibolite that was intruded by foliation-parallel veins of gneissic tonalite. The total-gas integrated age for hornblende from AM98-7116A is 2662 ± 15 Ma. Two aliquots, consisting of 4 and 6 steps each, yield similar age spectrum patterns. Both aliquots exhibit old, low-power steps, interpreted to result from the presence of excess Ar. Excluding steps with significantly older apparent ages, a pseudo-plateau age of 2513 ± 14 Ma (Figure 6-2e) has been calculated using 80% of total gas evolved.

Sample YD98-3044 was taken from the upper tectonostratigraphic unit of the Yathkyed Lake greenstone belt (Figure 6-1). Three aliquots yield irregular age spectrum patterns. Aliquot 1 displays extremely high apparent-age gas fractions for high-power steps. Aliquot 2 displays moderate high apparent-age gas fractions for high power steps, and overall, gives a "convex-down" age spectra. Aliquot 3 displays irregular apparent ages. Excluding steps with significantly older apparent ages, it yields an pseudo-plateau age of 1744 ± 12 Ma (44% of the total gas evolved; Figure 6.2f). This age is considered to be unreliable as data do not fall on a straight line on an inverse isochron plot, possibly

because of excess argon within the sample. This sample also contained large Ca/K ratios, indicating that analysed amphibole grains may have been actinolitic in composition.

Nowyak shear zone

Three samples from amphibolite enclaves within the Nowyak shear zone were chosen for ^{40}Ar - ^{39}Ar geochronology. MT98-129 is a fine-grained amphibolite from the western limb of the shear zone (Figure 6-1). This sample contains hornblende, actinolite, plagioclase and quartz, with minor amounts of chlorite, apatite and epidote. Euhedral to subhedral hornblende grains define the main (S_{my}) foliation. MT98-129 yielded a total-gas integrated age of 1659 ± 11 Ma. Three aliquots of hornblende, with 4 to 8 steps each, define relatively poor age spectrum patterns. Aliquot 1 shows fair variability in age among the steps, displaying apparently low age fractions at the beginning and middle of the gas-release spectrum. This is interpreted to reflect the presence of actinolite within the sample, as observed within thin section. Aliquots 2 and 3 display similar convex-down age spectrum patterns, with Ar-loss in the low-power steps. This is interpreted to reflect diffusive Ar-loss related to a secondary thermal disturbance. Excluding low apparent-age gas fractions, the combined age of the plateau portions give an age of 1775 ± 12 Ma (Figure 6-2g), and make up 64% of total gas evolved.

Sample MT98-157 is a protomylonite from within the Nowyak shear zone (Figure 6-1). It is an amphibolite comprised of medium- to coarse-grained hornblende and actinolite in a matrix of fine-grained plagioclase and recrystallized quartz. Hornblende occurs as euhedral to subhedral grains or grain aggregates, parallel to S_{my} . This sample yielded a total-gas integrated age of 2265 ± 14 Ma. Three aliquots of hornblende,

consisting of 6 and 7 steps each, resulted in relatively poor age spectrum patterns. Aliquot 1 displays low apparent-age gas fractions for low-power steps. Aliquots 2 and 3 show Ar-loss at lower and mid-power heating steps. Within all aliquots, Ar-loss is associated with steps containing relatively high Ca/K ratios, suggesting that these aliquots were predominantly actinolite. Using 60% of the total ^{39}Ar released by two aliquots, this sample yields a poor pseudo-plateau age of 2285 ± 15 Ma (Figure 6-2h).

Two samples (MT98-137a and 137b) from the eastern limb of the Nowyak shear zone were analysed (Figure 6-1). Both samples are medium- to coarse-grained amphibolites composed of hornblende, chlorite, plagioclase and recrystallized quartz, with minor actinolite and epidote. In MT98-137a, hornblende is typically euhedral to subhedral, parallel to S_{my} , and some layers locally contain radiating hornblende rosettes (sample MT98-137b) that crosscut the S_{my} foliation, and are interpreted to have developed after the deformation that generated S_{my} . Sample MT98-137a yielded a total-gas integrated age of 1198 ± 9 Ma. Two aliquots, consisting of 6 and 5 steps, respectively, display similar age spectra displaying significant Ar-loss at the beginning and end of the spectrum. A poor plateau age (Figure 6.2i) of 1445 ± 11 Ma is calculated using the middle power steps of both aliquots, and is interpreted to represent a minimum age. This age is not considered to be reliable as the sample contained a significant amount of excess argon.

MT98-137b gives a total-gas integrated age of 1807 ± 12 Ma. Three aliquots, each consisting of 4 to 5 steps, result in similar convex-down age spectrum patterns. Significant Ar-loss occurs at the beginning and end of the gas-release spectrum, and is

associated with steps containing relatively high Ca/K ratios, suggesting these samples may be predominantly actinolite. A pseudo-plateau age of 1792 ± 12 Ma (Figure 6-2j) was calculated using 43% of the total ^{39}Ar released by the three aliquots.

Footwall rocks

Nowyak metagranite

Sample IL96-2301 (Figure 6-1) is a medium- to coarse-grained, 2-mica metagranite containing plagioclase, potassium feldspar, and quartz, with minor amounts of muscovite and biotite. Euhedral muscovite defines the main (S_m) foliation, and yielded a total-gas integrated age of 1748 ± 11 Ma. Two aliquots, consisting of 11 and 8 steps, respectively, resulted in relatively flat age spectrum patterns, with the exception of minor Ar-loss at the beginning and end of the gas-release spectrum for aliquot 1. A plateau age of 1748 ± 12 Ma was calculated using 97% of the total ^{39}Ar released by the two aliquots (Figure 6-2q).

Sample MT98-167 (Figure 6-1) is a medium- to coarse-grained sample of the Nowyak metagranite containing plagioclase, potassium feldspar, and quartz, with minor biotite and muscovite; biotite is locally replaced by chlorite. Euhedral biotite defines S_m , and analyzed grains yielded a total-gas integrated age of 1725 ± 11 Ma. Three aliquots, each consisting of 6 to 10 steps, resulted in comparable convex-down age spectrum patterns, with minor Ar-loss at the beginning and end of the gas-release spectra for aliquots 1 and 2. This is interpreted to represent recoil of Ar atoms during irradiation. Excluding low apparent-age gas fractions, a plateau age of 1741 ± 11 Ma (Figure 6-2n) was calculated using 82% of the total ^{39}Ar released by the three aliquots.

Stonecutter supracrustal unit

Sample MT98-145 (Figure 6-1) is a medium-grained pelitic schist, containing biotite, muscovite, kyanite, garnet, quartz, and plagioclase. Euhedral biotite and muscovite define the main S_m foliation. The total-gas integrated age for muscovite is 1746 ± 12 Ma. One aliquot consisting of 10 steps gives an excellent flat-age spectrum, yielding an identical plateau age of 1746 ± 12 Ma (Figure 6-2). The total-gas integrated age for biotite is 1726 ± 11 Ma. One aliquot consisting of 11 steps yields a convex-down age spectra, with Ar-loss indicated by the younger apparent ages of the first gas fractions. This is interpreted to represent Ar-recoil during irradiation. Excluding low apparent-age gas fractions, a plateau age of 1757 ± 11 Ma (Figure 6-2) is calculated using 78% of the total Ar released, and is interpreted to represent a maximum age.

Sample MT98-102 (Figure 6-1) is a medium-grained garnet amphibolite, consisting of hornblende, plagioclase, quartz, and garnet, with minor amounts of biotite. Euhedral to subhedral hornblende define S_m ; the total-gas integrated age is 1732 ± 11 Ma. Three aliquots, consisting of 3 and 6 steps each, yield relative flat age spectra, with moderate Ar-loss at the end of the spectrum (high-power) for aliquot 1 and 2 and at the beginning of the spectrum (low power) for aliquot 3. This is interpreted to represent diffusive loss of Ar related to a secondary thermal disturbance. A plateau age of 1775 ± 12 Ma (Figure 6-2) was calculated using 85% of the total ^{39}Ar released by the three aliquots.

Sample MT98-145 (Figure 6-1) is a similar garnet-amphibolite from the Stonecutter supracrustal unit. The total-gas integrated age is 1774 ± 11 Ma. One aliquot,

consisting of 10 steps, yields an excellent flat age spectrum, with minor Ar-loss in the two lowest power steps. Excluding these latter steps, a plateau age of 1804 ± 12 Ma (Figure 6-2) is calculated using 84% of total gas evolved.

6.3.3 Discussion of ^{40}Ar - ^{39}Ar results

Two samples analysed from the southwestern portion of the Kaminak Lake greenstone belt yield hornblende ^{40}Ar - ^{39}Ar ages ranging from ca. 1770 to 1775 Ma, similar to hornblende plateau ages documented by H. Sandeman (2001), which were ca. 1712 - 1750 Ma. As the core of the Kaminak Lake greenstone belt preserves Archean U-Pb crystallization ages ranging from ca. 2623 - 2660 Ma (Sandeman, 2001), these ages are interpreted to represent cooling ages associated with Proterozoic resetting along the margins of the greenstone belt, possibly related to the intrusion of the Hudsonian granites at 1.83 Ga (Peterson, 2000).

For the northern portion of the Yathkyed Lake greenstone belt, three samples (YD98-3044, BH98-9059, and AM98-7116) were analysed. Excluding YD98-3044, they yielded ^{40}Ar - ^{39}Ar hornblende plateau ages ranging from ca. 2460 - 2513 Ma, similar to K-Ar ages determined by Eade (1986), which ranged from ca. 2430 - 2485 Ma. YD98-3044 contained excess argon, interpreted to be related to the intrusion of a nearby pluton, and is not considered to yield a reliable age (see above). In the southern part of the Yathkyed greenstone belt, hornblende analysed from sample CR96-1302 yielded a Neoarchean pseudo-plateau age of 2670 ± 16 Ma, with an inverse correlation age of 2630 ± 78 Ma for all of the gas steps. The correlation age is interpreted to be the best estimate of the cooling age of the hornblende (Sandeman, 2001). Proterozoic resetting of

hornblende grains is not observed within the Yathkyed greenstone belt, though it should be noted that the tectonothermal history a large portion of the belt has not been examined using K/Ar or ^{40}Ar - ^{39}Ar geochronology.

Generally, the Nowyak complex yielded similar hornblende plateau ages to those obtained from the margins of the Kaminak Lake greenstone belt. With the exception of one sample located within the Nowyak shear zone (MT98-157) that gave a hornblende plateau age of ca. 2285 Ma, ^{40}Ar - ^{39}Ar cooling ages range from ca. 1775-1804 Ma. As discussed in section 6.3.2, the Paleoproterozoic age obtained from MT98-157 is not considered to be particularly reliable age for two reasons: (1) the two aliquots yielded a poor age spectrum; and (2) the amphiboles analysed were partially actinolite. This older age suggests that the shear zone may have nucleated in Archean rocks, though the majority of the shear zone likely reflects Proterozoic resetting of hornblende similar to that observed north of the Kaminak Lake greenstone belt *proper* (defined by Sandeman as that part which is not affected by Proterozoic resetting; Sandeman, in press, 2001).

For samples in the footwall of the Nowyak complex, ^{40}Ar - ^{39}Ar plateau ages obtained for muscovite and biotite plateau ages are ~ 1746 - 1748 Ma and ~ 1741 - 1760 Ma, respectively. These ages are similar to the ca. 1740 - 1780 Ma ages obtained throughout both the Yathkyed Lake and Kaminak Lake greenstone belts.

Regional comparison of ^{40}Ar - ^{39}Ar plateau ages from hornblende, muscovite, and biotite from the Nowyak complex to those from the Kaminak Lake and Yathkyed Lake greenstone belts indicate that after ca. 1.83 Ga, the Nowyak complex did not experience a late cooling history separate from the reworked Yathkyed or Kaminak Lake greenstone

belts. Together, the Yathkyed and Kaminak Lake greenstone belts make up a north-south “reworked” corridor between the Yathkyed and Kaminak Lake greenstone belts *proper* (Sandeman, in press, 2001). In order to construct a thermal history for the region, approximate mineral closure temperatures of 500 °C for hornblende (Reynolds, 1992), 350 °C for muscovite (Reynolds, 1992), and 280 °C for biotite (Reynolds, 1992; McDougall and Harrison, 1988) are used. Rocks have been affected by a Paleoproterozoic tectonothermal event at temperatures above 500 °C, the closure temperature of hornblende. The duration of this event is unknown, though comparison between ^{40}Ar - ^{39}Ar hornblende ages (ranging from ca. 1804 to 1775 Ma) and biotite ages (ranging from ca. 1760 to 1741 Ma) suggests slow cooling, in the order of between 5 to 20 °C/Ma.

This event may be related to the intrusion of the ca. 1.83 Ma Hudsonian granitoids, one large pluton of which is located immediately south of the Nowyak complex. Biotite and muscovite ages overlap, within error, and are interpreted to indicate rapid cooling through the muscovite and biotite closure temperatures. They may have been affected by the intrusion of ca. 1.75 Ma Nueltn granitoids, though no plutons occur in the area.

6.4 U-Pb geochronology

Zircon is an ideal mineral for U-Pb geochronology in igneous and metamorphic rocks because it is relatively chemically inert, has a high retentivity for radiogenic Pb, and shows a strong preference for U over Pb during crystallization. U-Pb isotope ratios are most commonly measured using isotope dilution thermal ionization (ID-TIMS), but are increasingly analysed using new technology such as the sensitive high resolution ion

microprobe (SHRIMP). U-Pb analyses using an ion microprobe (SHRIMP) permits in-situ material (1 - 10 ng) analysis of grains, enabling complex geochronological targets, such as zoned zircons, to be analyzed (Stern, 1997).

In an effort to determine the timing of high-pressure metamorphism within the footwall rocks of the Nowyak complex, zircons were analysed from three zones of textural complexity: (1) garnet porphyroblasts, (2) garnet breakdown zones, and (3) the biotite-kyanite-muscovite-plagioclase-quartz matrix.

6.4.1 Analytical methods

An epoxy mount containing in-situ zircons for analysis, and the GSC Kipawa standard was made. The midpoints of the grains were exposed by polishing with a diamond compound. Using the SEM, individual zircon grains, in-situ within the rock puck, were imaged using both BSE (Back-scattered Electron microscopy) and CL-mode (CathodoLuminescence Electron microscopy). The zircon images were subsequently used to characterize morphology, fractures, inclusions, and for the presence of zoning (primary vs. metamorphic). Due to scale problems (e.g., the focusing of a 5 x 10 μm image, especially in CL-mode; see Figure 6-3a-v), it was difficult to interpret textural relationships of internal morphological features. Nonetheless, an effort was made to describe and characterize zircons in terms of their size and morphology, in such a manner that grains which were too small ($<5\mu\text{m}$), and those which contained numerous inclusions, and/or complex zoning patterns were given low priority for analysis.

The entire epoxy disk was lightly coated with a thin layer of gold (6 - 8 nm) prior to SHRIMP analysis. Chosen spots were sputtered using a mass-filtered primary O^+ beam

with a current ranging from 0.5 - 5 nA. Resulting pits (or spots) were elliptical with flat bottoms and shallowly sloping sides, and were $\sim 5 \mu\text{m}$ in diameter and $1 \mu\text{m}$ in depth. Imaging of zircons after analysis was done in order to locate the precise position of analytical spots. Each analysis consisted of between 6 to 8 runs, with variable peak collection times. The data were reduced following parameters outlined by Stern (1997), and common-Pb corrections were made using the reference curve of Cumming and Richards (1975). All uncertainties reported in text are given at 1σ and are calculated by numerical propagation of all known sources of error (Stern, 1997). Data plotted on concordia are calculated with 2σ error ellipses. All analyses give significantly large age errors.

6.4.2 Zircon Descriptions

A total of 26 zircons were analysed from sample BLB97-005, a biotite-kyanite-muscovite-garnet pelitic schist obtained from the Stonecutter supracrustal unit. 18 zircon grains were identified within a 6mm-diameter garnet porphyroblast, however, 2 grains ($\sim 3 \mu\text{m}$ in diameter) were too small to be analysed using the SHRIMP microprobe. Zircons analysed were typically very small ($< 20 \mu\text{m}$ in diameter) and showed a wide range in crystal morphology, including hints of primary zoning crosscut by possible recrystallization zones (Figure 3-6a-r). Due to size limitations and low-Pb counts, 6 analyses were either aborted during analysis or yielded unusable data. The remaining 9 zircon inclusions that were analysed are described in more detail below.

Within the matrix of sample BLB97-005, 6 zircons were identified as good candidates for analysis. These grains occurred either as inclusions in biotite, or interstitial

to foliation-parallel biotite and muscovite. Similar to garnet zircons, grains display a variable morphology (Figure 6-3s,t). Of the 6 analyses, 5 were aborted during analysis due to low Pb counts. The one analysed grain (MZ1) is described in more detail below.

Two zircons were observed in the garnet breakdown zone. Zircons from this textural zone display a wide variation in morphology (Figure 6-3u,v), are generally found along grain boundaries of plagioclase, biotite and quartz, and produced by breakdown reactions 1 and 2 (see section 5.3.1). One analysis was aborted due to low-Pb counts.

Zircon inclusions in garnet

Nine zircons (Figure 6-3a - v) from a garnet porphyroblast were analysed. The garnet is ~ 6.0 mm in diameter and relatively free of fractures. A well-developed fabric, defined by the long axis of kyanite, muscovite, biotite, plagioclase, and quartz, wraps around the garnet porphyroblast. Other garnet porphyroblasts within the sample have curved inclusion trails of quartz and plagioclase. Together, these observations are consistent with pre- to syn-kinematic garnet growth. The garnet is surrounded by a reaction rim of variable width (>1.5 mm), that dominantly consists of randomly oriented biotite, muscovite, plagioclase, and quartz. Most zircons are located within 1.0 mm of the garnet rim, with the exception of two extremely small zircons (<3 μm in diameter) that were unsuitable for analysis because of their size.

Zircon #4 (Figure 6-3a, b) is ~150 μm inside the garnet reaction rim. It is approximately 20 by 20 μm in size, anhedral, and is partially embayed along 2 edges. The zircon displays oscillatory zoning that is abruptly truncated by the garnet porphyroblast, and contains numerous inclusions of unknown composition (<1 μm in

diameter). CL imaging shows bright patches along the zircon rim which spatially correspond to muted grey zones on the BSE image, and both cut the oscillatory zonation pattern. This may possibly be related to partial zircon recrystallization. Two spots were analysed from this zircon. Spot 4.1 straddled a grain boundary; analysis at this spot showed high common Pb (37 ppb), and yielded a $^{207}\text{Pb}/^{206}\text{Pb}$ age of 1915 ± 173 Ma (96.6% concordant). Spot 4.2 is in the inclusion-rich/oscillatory-zoned core of the zircon. Analysis of this spot contained high common Pb (36 ppb), and yielded an old $^{207}\text{Pb}/^{206}\text{Pb}$ age of 2280 ± 34 Ma (96.2 % concordant).

Zircon #5 (Figure 6-3c, d) is ~ 500 μm inside the garnet reaction rim, and ~ 40 μm distant from a <10 μm -wide internal garnet fracture. Z5 is 7 by 10 μm in size, euhedral, and is not visibly zoned, with the exception of a small patch of moderate CL brightness visible in one corner of the grain. The zircon contains 3 small inclusions (< 2 μm in diameter) of unknown composition. One spot analysis from the core of the grain has low common Pb (1 ppb), and yielded a $^{207}\text{Pb}/^{206}\text{Pb}$ age of 2194 ± 49 Ma (95.8 % concordant).

Zircon #6 (Figure 6-3e, f) is located ~ 550 μm away from the garnet edge, and ~ 50 μm away from a cross-cutting fracture (10 μm in width) in the garnet. Z5 is subhedral, small (7 by 12 μm in size), and partially embayed along one edge. It contains 2 inclusions (< 1 μm in diameter) of unknown composition. BSE images show no significant zoning, although CL imaging does show bright patches along the edge of the grain. The analysis contains a significant amount of common Pb (24 ppb), consistent with its location on a grain boundary, and yielded a $^{207}\text{Pb}/^{206}\text{Pb}$ age of 2130 ± 56 Ma (105 % concordant).

Zircon #7 (Figure 6-3g, h) is an anhedral grain located ~ 950 μm away from the garnet rim, and 100 μm away from a fracture cross-cutting the garnet (up to 50 μm in width). A small fracture (<1 μm in width) runs through the zircon grain. The zircon grain is 7 by 13 μm in size, and contains inclusions of rutile and Fe-oxides. CL imaging displays two small bright patches along the zircon rim which spatially correspond to muted grey zones on the BSE image, suggesting that these may be areas of partial zircon recrystallization. One spot, analysed in the core of the grain, has moderate common Pb (4 ppb), and yielded a $^{207}\text{Pb}/^{206}\text{Pb}$ age of 1966 ± 27 Ma (111.1% concordant).

Zircon #9 (Figure 6-3i, j) is ~300 μm from the edge of the garnet, and ~ 150 μm distant from a large fracture in garnet (10 - 15 μm in width). Z9 is a small (12 by 15 μm in size) anhedral grain with partially embayed sides, and contains numerous Fe-oxide inclusions. BSE imaging hints at an oscillatory growth zonation pattern. CL images display one small bright patch along the zircon rim, spatially corresponding to a muted grey zone on the BSE image, interpreted to represent an area of partial zircon recrystallization. Two spots, Z9.1 and Z9.2, were analysed from this grain, and both straddled a grain boundary. The spots contain 64 and 4 ppb of common Pb, and yielded $^{207}\text{Pb}/^{206}\text{Pb}$ ages of 1842 ± 287 Ma (104.7% concordant) and 1975 ± 116 Ma (95.3% concordant), respectively.

Zircon #13 (Figure 6-3k, l) is ~550 μm away from the edge of the garnet, and contains a small fracture (< 1 μm in width). It is an anhedral grain (6 by 20 μm in size), partially embayed along one edge, and contains one small inclusion (2 μm in diameter) of unknown composition. The core of the grain preserves evidence of zoning, and CL

imaging shows moderate bright patches generally located at the zircon rim. Due to the small size of the grain, and related imaging problems, it is unclear what the nature and origin of the zonation is. Spot Z13, analysed on a bright patch, has high common Pb (32 ppb), and yielded a $^{207}\text{Pb}/^{206}\text{Pb}$ age of 2041 ± 117 Ma (92.5% concordant).

Zircon #14 (Figure 6-3m, n) is an anhedral grain located ~ 250 μm away from the edge of the garnet. It has 2 internal fractures which do not appear to connect to any fractures in the host garnet. The zircon (7 by 12 μm) does not show obvious zoning when examined in BSE mode, and although CL imaging shows one small bright patch along the zircon rim, no interpretation as to the nature of the bright patch can be made. Spot Z14, analysed from the core of the grain, has low common Pb (1 ppb), and yielded a $^{207}\text{Pb}/^{206}\text{Pb}$ age of 2084 ± 75 Ma (97.9% concordant).

Zircon #15 (Figure 6-3o, p) is ~ 750 μm away from the garnet edge, and is ~ 74 μm distant from a small fracture in the host garnet. The zircon does not contain any internal fractures. The zircon, ~ 7 by 15 μm in size, is subhedral and contains an inclusion-rich core (unknown composition). CL imaging displays two bright patches located along the zircon rim, which spatially correspond to muted grey zones (inclusion-poor) on the BSE image, tentatively interpreted to represent areas of partial zircon recrystallization. One spot analysed from this grain landed on a grain boundary and contained low common Pb (1 ppb), yielding a $^{207}\text{Pb}/^{206}\text{Pb}$ age of 2050 ± 84 Ma (99.6% concordant).

Zircon #16 (Figure 6-3q, r) is a sub-to euhedral grain located ~ 250 μm away from the garnet edge. The zircon is adjacent (<5 μm) to a cross-cutting fracture in the

host garnet. The zircon core contains a moderate number of small ($< 1 \mu\text{m}$ in diameter) inclusions of an unknown composition, and one “large” ($\sim 3 \mu\text{m}$ in diameter) plagioclase inclusion. Though no obvious zoning is observed within the zircon grain, CL images display two small bright patches along the zircon rim which spatially correspond to muted grey zones (inclusion-poor) observed in the BSE images. This may suggest partial zircon recrystallization along the zircon rim. Although spot Z16 partially straddles a grain boundary, it contains a low amount of common Pb (1ppb, and yielded a $^{207}\text{Pb}/^{206}\text{Pb}$ age of $1780 \pm 132 \text{ Ma}$ (114.3% concordant).

Zircons located within the matrix or the garnet breakdown zone

Zircon #20 (Figure 6-3s, t) is located in the rock matrix, distal to the garnet porphyroblast. It is an inclusion in a biotite which defines the main fabric. MZ1 is euhedral, ~ 10 by $12 \mu\text{m}$ in size, and has no obvious zoning. Though CL imaging shows one bright patch, grain, due to the small size of the grain and related imaging problems, it is unclear what the nature of this patch is. The zircon contains a branching fracture near one corner of the grain. The spot analysed had high common Pb (29 ppb), and yielded a $^{207}\text{Pb}/^{206}\text{Pb}$ age of $2097 \pm 174 \text{ Ma}$ (88.7% concordant).

Zircon #30, (Figure 6-3u, v) is located in the breakdown zone of the garnet, in a chloritized biotite grain. It is ~ 12 by $18 \mu\text{m}$ in size, anhedral, and embayed along 2 edges. Internally, large fractures cross-cut the grain, and may represent the beginning stages of zircon breakdown. CL imaging displays bright patches along the zircon rim, which spatially correspond to muted grey zones on BSE images, and may suggest partial

zircon recrystallization. Spot Z30 included a zircon fracture, had extremely high common Pb (224 ppb), and yielded a $^{207}\text{Pb}/^{206}\text{Pb}$ age of 1908 ± 180 Ma (89.3% concordant).

6.4.3 Analysis of data

Population distribution

A total of 13 spots from which 11 zircons were analysed. As the zircon grains are extremely small, it is nearly impossible to determine whether zircons are detrital or metamorphic in origin on the basis of texture alone. As such, uranium concentrations, Th/U ratios, and the wide range in ages are used to make this distinction. "Metamorphic" values are generally considered to be less than ca. 0.1, whereas "magmatic" values are generally greater than ca. 0.4 (Stern and Berman, 2000; Heaman et al., 1990; Schaltegger et al., 1999). Uranium concentrations for zircons from the Stonecutter supracrustal unit range from 158 to 1459 ppm, and Th/U ratios fall between 0.01 -0.49. Zircons from the Stonecutter supracrustal unit have Th/U ratios which are typical of magmatic zircons. Since the zircons are contained in a metasedimentary rock, and they are unlikely to be metamorphic based on Th/U ratios and textural evidence, they are interpreted to be detrital zircons with an internally igneous provenance.

It is difficult to impossible to determine whether grains belong to one or multiple populations, as the quality of the data does not allow for the determination of population statistics. All analyses had large errors associated with them, ranging from 27 to 287 Ma, making statistical procedures meaningless. However, reasonably small errors associated with the $^{207}\text{Pb}/^{206}\text{Pb}$ ages of two grains, Z4.2 and Z7 (2281 ± 32 Ma and 1966 ± 27 Ma, respectively) hint at the possibility of more than one population.

According to the data, high-U zircons generally also have correspondingly low levels of common Pb (Figure 6.4a), though some low-U zircons also contain low levels of common Pb. High ^{204}Pb is a common feature of the grain boundary analyses, in inclusion-rich grains (Figure 6.4b), and/or grains that have large internal fractures (Figure 6.4c).

With increasingly high levels of common Pb, errors on the $^{207}\text{Pb}/^{206}\text{Pb}$ ages also increase, thus reducing the reliability of the analysis. The confidence level increases with those analyses having lower common Pb levels. The most confident analysis come from analysis that were placed to: (1) avoid zircon fractures and inclusions, (2) land entirely within the zircon grain, and (3) placed entirely within a zone subgrain (e.g. does not straddle two separate growth zones, where identifiable). Analysis with $\ll 1$ ppb common Pb have the greatest confidence level, whereas those with moderate to high common Pb (> 5 ppb) have a low confidence level associated with them. Based on this criterion, only six zircons give $^{207}\text{Pb}/^{206}\text{Pb}$ ages that are considered to have reasonable confidence levels: Z14, Z16, Z7, Z9.2, Z15, and Z5. These ranged in age from 1780 (± 132) - 2194 (± 49) Ma.

All 14 fractions have been plotted on a U-Pb concordia diagram (Figure 6-5), however, analyses with a greater confidence level have been shaded in grey. Owing to large (2σ) uncertainties of the 14 grains analysed, discordance is difficult to assess. For example, the majority of analysis give discordant $^{206}\text{Pb}/^{238}\text{U}$ and $^{207}\text{Pb}/^{235}\text{U}$ ages (Table 6-2). But when these analyses are plotted on concordia, taking into account the huge error

associated with calculated ages, most touch the concordia curve. It is difficult to correctly discriminate between different population ages (e.g. crystallization vs. metamorphic ages). Normal discordance is generally interpreted to be the result of Pb-loss, whereas reverse discordance is commonly seen in high-U or metamict zircon, and is attributed to SHRIMP matrix calibration effects (e.g. the analysed zircon does not have the same crystallinity as the standard). Although Pb-loss systematics are complicated, it may be attributed to any or a combination of the following: continuous diffusion, radiation damage, chemical weathering, hydrothermal alteration, an episodic event such as metamorphism, mixing events, or a combination of the above (Faure, 1986).

Continuous diffusion

Cherniak et al. (1997) examined the diffusion rates for three rare-earth elements (Sm, Dy, Yb), and found that although there is a systematic increase in diffusivity with increasing ionic radius (HREEs), diffusivities are generally so small ($\ll 10^{-30} \text{ m}^2 \text{ s}^{-1}$) as to be considered to be geologically insignificant. For example, diffusion over a billion years at temperatures of 800 °C will result in diffusion distances on the order of several nm, even at temperatures of 1000 °C, diffusion distances will only amount to a few tens of μm over the same time period (Cherniak et al., 1997; Lee et al., 1997). As such, continuous diffusion as a principal means of producing discordance for zircons from the Nowyak footwall is rejected.

Radiation damage

Minerals will become “metamict” (damaged crystal lattice structure) as a result of radiation damage by alpha-decay of U, Th, and their daughter products (Meldrum et al.,

1998). The potential extent of damage increases with age and U-and Th-content of the minerals (Faure, 1986), with the most heavily altered areas occurring in the outer zones of high-U crystals. Although several other processes can lead to radiation damage in minerals, such as β -decay and spontaneous nuclear fission, most of the atomic displacements leading to metamictization are caused by α -recoil nuclei (Schaltegger et al., 1999). Meldrum et al. (1998) developed a formula allowing for the calculation of N_c (the present-day concentration above which the mineral should be metamict from age t years and temperature T ; $T = 25^\circ\text{C}$), where

$$(1) N_c(\text{ppm}) = 166 / \{ [1 - e^{1.1 \cdot (1-633/T)}] * (e^{1.55 \cdot (10^{-10}) \cdot t} - 1) \}.$$

This equation can be used to estimate the reliability of U-Pb ages, particularly from samples with high-U content. Rocks within the Nowyak footwall cooled through 280°C (biotite closure temperature) at ca. 1750 Ma. Given a cooling rate of $5\text{--}20^\circ\text{C/Ma}$, t at 25°C (T) will occur between ca. 1700 to ca. 1730 Ma. Substitution into equation 1 indicates that zircons containing greater than 760 ppm of U should be metamict. Two Nowyak zircon grains contain U contents significantly greater than 760 ppm (Z7 and Z9.2 have 1339 and 1459 ppm of U, respectively), that their discordant analysis may be related to loss of radiogenic Pb due to radiation damage.

Chemical weathering/Hydrothermal alteration

Chemical weathering is most likely to occur in rocks that have been at the surface for a significant period of time. Zircon is relatively insoluble in crustal melts and fluids, resisting chemical and physical breakdown, often results in several geochemical growth zones in a single grain (refer to section 6.4.2; Cherniak et al., 1997). If recent Pb-loss has

occurred (e.g. while the rock has been at the surface), disturbances of the daughter to parent ratios ($^{206}\text{Pb}/^{238}\text{U}$ and $^{207}\text{Pb}/^{235}\text{U}$) result in discordia chords that passes through the origin (Faure, 1986). Although crystals from the Nowyak complex have large errors associated with their analyses, the concordia diagram does not represent a pattern consistent with recent Pb-loss.

Episodic event

Episodic events, such as one or more protracted periods of metamorphism and/or deformation, often cause Pb to be lost from the system, resulting in “reset” ages or mixtures of several different ages of radiogenic Pb. Hanchar and Millar (1993) suggested that apparent Pb-loss during high-grade metamorphism is more likely due to recrystallization and/or growth of new grains or rims on preexisting grains, than it is to diffusive processes. Growth domains with primary zoning may be replaced by secondary growth, often with elevated concentrations of REEs that give brighter CL images. Schaltegger et al. (1999) suggest that these structures represent migrating chemical reaction fronts that “rejuvenate” the U-Pb systematics. Discordance may also be caused by the ion-beam landing on two separate growth zones of zircon (e.g. operator error).

CL and BSE imaging is critical to the interpretation of whether resetting is caused by metamorphism. Zircons from the Nowyak footwall exhibit textural features that hint at prior primary zonation patterns (Z4, Z9, Z13, and AZ1), and most zircons display bright patches concentrated along their rims. This is interpreted to represent partial recrystallization during a metamorphic event.

6.4.4 Discussion

Extremely large $^{207}\text{Pb}/^{206}\text{Pb}$ errors make data interpretation difficult. Analyses from zircon fractions do not appear to define a discordia chord, nor do they cluster around one age. The most confident $^{207}\text{Pb}/^{206}\text{Pb}$ ages are given by near-concordant zircon analyses (Z14, Z16, Z7, Z9.2, Z15, and Z5) containing little to no common Pb that had relatively small errors associated with them, and range in age from 1780 (± 132) to 2194 (± 49). Discordance in ages appears to have been caused by both metamictization and radiogenic Pb loss during metamorphism, but is not attributed to continuous diffusion or chemical weathering.

A wide range in Th/U ratios between 0.01 to 0.49, primary zoning, and the wide range in ages are inconsistent with an interpretation of metamorphic zircons, and are interpreted to indicate a detrital zircon population with an igneous provenance. However, it is uncertain whether it is comprised of Proterozoic detrital grains or Archean detrital grains that have been reset. If the sedimentary protolith is Archean in age, then all detrital zircons analysed have been partially and variably reset by a metamorphic event during the Proterozoic, sometime after the youngest age of the zircon (1966 ± 53 Ma). Alternatively, the zircons may not be reset, and may preserve original igneous ages. Resetting of zircons is achieved at extremely high temperatures ($> 700^\circ\text{C}$) - conditions which are not recorded in the Nowyak complex (660°C). This, combined with textural evidence of oscillatory zoning preserved within zircon cores, suggests some zircons did not experience recrystallization, and may indicate that the Stonecutter supracrustal unit is

a Proterozoic sediment younger than the age of the best constrained zircon of 1966 ± 53 Ma.

The possibility that zircons from the Stonecutter Supracrustal unit are Proterozoic in age warrants comparison with members of the Hurwitz Group. Davis et al. (2000) reports detrital zircon ages ranging from 2500 Ma to < 1950 Ma in the upper Hurwitz Group. Within the Watterson Formation, U concentrations range between 36 - 1177 ppm, with Th/U ranging from 0.041 - 1.456 (Davis, personal communication, 2001). The Tavani Formation contains zircons with 30 - 388 ppm of U, and Th/U ratios ranging from 0.265 - 1.539 (Davis, personal communication, 2001). The two lower Hurwitz members, the Padlei and Kinga Formations, cannot be considered to be a source as the ca. 1.96 Ga Thelon orogeny had not yet occurred. On average, U concentrations from Nowyak (158 - 1459 ppm) are similar to those within the Watterson Formation, but Th/U ratios are generally lower than those observed in both the Watterson and Tavani Formations. Tentatively, based on the very limited data from the Nowyak complex, it appears that the Stonecutter supracrustal unit cannot be correlated with the upper Hurwitz Group.

6.5 Conclusions

The Stonecutter supracrustal unit, part of the Nowyak complex contains 1780 ± 132 to 2194 ± 49 Ma detrital (?) zircons (this study), indicating that unit is a Proterozoic sediment younger than the age of the best constrained zircon (1966 ± 53 Ma), and ca. 1820 Ma monazite (Berman et al., 2000). M1 may have occurred at ca. 1.9 Ga, the age of high-P metamorphism determined elsewhere (Berman, 2000). Alternatively, garnet growth during high-pressure metamorphism and associated uplift and granitic plutonism

may have occurred at ca. 1.82 Ga, the age of monazite grains. Monazite grains, which are foliation-parallel, are interpreted to be syn-kinematic to garnet growth.

^{40}Ar - ^{39}Ar cooling rates, using approximate mineral closure temperatures for the Nowyak complex, yield plateau ages of ca. 1775-1804 Ma for hornblende, ca. 1748-1746 Ma for muscovite, and ca. 1760-1741 Ma for biotite, similar to ages calculated outside of the complex within the Kaminak and Yathkyed Lake greenstone belts. Based on the data, the Nowyak complex did not experience a late cooling history separate from the reworked Yathkyed or Kaminak Lake greenstone belts, which together make up a north-south "reworked" corridor between the southern edge of the Yathkyed Lake greenstone belt *proper* and the northern edge of the Kaminak Lake greenstone belt *proper* (Sandeman, in press, 2001). The data indicate that the rocks exposed in the corridor cooled through 500 °C, the closure temperature of hornblende, between ca. 1775 - 1800 Ma. This may be related to cooling after the intrusion of the ca. 1.83 Ga Hudsonian granitoids, of which one large pluton is located immediately south of the Nowyak complex (Peterson, personal communication, 2001). Biotite and muscovite ages overlap, within error, and are interpreted to indicate rapid cooling at ca. 1750 Ma, through the muscovite and biotite closure temperatures at 350 °C and 280 °C, respectively. However, these ages may have been affected by the intrusion of ca. 1.75 Ga Nuelin granitoids, which occur throughout the Hearne sub-domain.

The present U-Pb data set is extremely limited due to large analytical errors resulting from the very small size of the zircons analysed. In order to determine the age of high-pressure metamorphism, conventional U-Pb methods (e.g. ID-TIMS) in

conjunction with further SHRIMP analyses should be attempted on many more samples from the area. Subsequent analyses may elucidate timing of metamorphic events, and would also help determine the provenance of the detritus (Hurwitz?) that comprises the Stonecutter supracrustal unit.

Figure 6-1: Location map for $^{40}\text{Ar}/^{39}\text{Ar}$ and SHRIMP geochronology samples.

Yathkyed Lake Greenstone belt

Legend

Proterozoic

Hurwitz Gr.

Archean/Proterozoic

Post-tectonic granitoid

Higher TS Unit

Psammitic-pelitic schists

Mixed volcanic rocks

Tonalite

Lower TS Unit

"Komatik" granite

Mafic Volcanics

Carnecksluck
intrusive suite
(synvolcanic)

N

20 km

Tyrrell Shear Zone

Mixed granitoid and
supracrustal rocks

Tyrrell Footwall

Mixed orthogneiss

Mixed supracrustal rocks

Calc-silicates

Syn-tectonic granitoids

Shear Zone

Synform

Antiform

Fault

Nowyak
Complex

Figure 6-2 (a-q): $^{40}\text{Ar}/^{39}\text{Ar}$ age spectra for hornblende, muscovite, and biotite. Steps used in calculation of the plateaux are coloured in black, unused steps are coloured in grey. P.A. = Plateau age; I.A. = Integrated age.

Figure 6-3 (a-v): Backscatter and cathodoluminescence SEM images for all analysed zircon grains (SHRIMP geochronology), sample BLB97-005. White circles indicate SHRIMP probe localities (pits).

Figure 6-4: Correlation graphs: a) U (ppm) concentration vs. ^{204}Pb (ppb) concentration, b) Fractures present vs. ^{204}Pb (ppb) concentration, and c) Inclusions present vs. ^{204}Pb (ppb) concentration.

A**U concentration vs. ^{234}Pb concentration** **B****Fractures present vs. ^{234}Pb concentration** **C****Internal inclusions vs. ^{234}Pb concentration**

Figure 6-5: U-Pb concordia plot (2σ error) for 9 single-crystal fractions from the Stonecutter supracrustal unit. Solid lines/grey fill indicates “confident” analysis; dashed lines/colourless fill indicates all other analysis. See text for details.

Table 6.1: Summary of the ^{40}Ar - ^{39}Ar age results from the Nowyak Complex and surrounding country rock.

Sample Number	Easting	Northing	Mineral dated	Size fraction (um)	Integrated age (Ma)	Plateau (minimum) age (Ma)
<i>Hanging Wall</i>						
BH98-9059	600900	6949500	Hbl	300 - 150	2493 +/- 14	2460 +/- 14
			Bt	300 - 150	1768 +/- 11	1785 +/- 11
AM98-7116	578225	6922425	Hbl	300 - 150	2662 +/- 15	2513 +/- 14
CR96-0532	549336	6856023	Hbl	300 - 150	1692 +/- 12	1769 +/- 12
IL96-2166	552096	6855760	Hbl	300 - 150	1735 +/- 12	1774 +/- 12
CR96-1302*	529870	6855283	Hbl	300 - 150	2901 +/- 16	2670 +/- 16
YD98-3044*			Hbl	300 - 150	1744 +/- 12	1795 +/- 12
<i>Shear Zone</i>						
MT98-129	532226	6851166	Hbl	300 - 150	1659 +/- 11	1775 +/- 12
MT98-157	535563	6853758	Hbl	300 - 150	2265 +/- 14	2285 +/- 15
MT98-137a*	541697	6849826	Hbl	300 - 150	1198 +/- 9	1445 +/- 12
MT98-137b	541697	6849826	Hbl	300 - 150	1856 +/- 12	1793 +/- 12
<i>Footwall</i>						
MT98-167	534301	6851217	Bt	300 - 150	1725 +/- 11	1741 +/- 11
IL96-2301	536673	6850532	Ms	300 - 150	1747 +/- 11	1748 +/- 11
MT98-146	536475	6845489	Bt	300 - 150	1726 +/- 11	1760 +/- 11
			Ms	300 - 150	1746 +/- 12	1746 +/- 12
MT98-102	537089	6845934	Hbl	300 - 150	1732 +/- 11	1775 +/- 12
MT98-145	536664	6845523	Hbl	300 - 150	1774 +/- 2	1804 +/- 12

* Excess argon; unreliable age

Table 6.2: SHRIMP analytical data^{1,2}

Labels	U ppm	Th ppm	Th/U	Pb* ppm	²⁰⁴ Pb ppb	²⁰⁴ Pb/ ²⁰⁶ Pb	²⁰⁴ Pb/ ²⁰⁶ Pb ±	²⁰⁸ Pb/ ²⁰⁶ Pb	²⁰⁸ Pb/ ²⁰⁶ Pb ±	²⁰⁷ Pb/ ²³⁵ U	²⁰⁷ Pb/ ²³⁵ U ±	²⁰⁶ Pb/ ²³⁸ U	²⁰⁶ Pb/ ²³⁸ U ±	²⁰⁷ Pb/ ²⁰⁶ Pb	²⁰⁷ Pb/ ²⁰⁶ Pb ±	²⁰⁶ Pb/ ²³⁸ U	AGE (Ma)
Z14	169	20	0.12	63	1	1E-05	0.00001	0.0355	0.0075	6.6203	0.5331	0.3724	0.0239	0.1290	0.0053	2041	
Z4.2	577	272	0.49	259	36	0.0002	6.7E-05	0.1432	0.0052	8.0753	0.3587	0.4056	0.0153	0.1444	0.0028	2195	
Z4.1R	405	77	0.20	137	37	0.0003	0.00039	0.0639	0.0162	5.3744	0.9020	0.3324	0.0432	0.1173	0.0107	1850	
Z16	326	83	0.26	124	1	1E-05	0.00001	0.0842	0.0092	5.5743	0.5101	0.3713	0.0193	0.1089	0.0075	2036	
Z6	580	163	0.29	253	24	0.0001	0.00022	0.0893	0.0097	7.5770	0.3917	0.4148	0.0155	0.1325	0.0042	2237	
Z13	148	2	0.02	49	32	0.0007	0.00034	0.0147	0.0136	5.9053	0.4923	0.3403	0.0158	0.1259	0.0080	1888	
Z7	1339	236	0.18	549	5	1E-05	0.00001	0.0609	0.0023	6.7110	0.2738	0.4034	0.0146	0.1207	0.0018	2185	
ZA1	307	41	0.14	86	224	0.0027	0.00062	-0.0414	0.0241	4.8914	0.5379	0.3036	0.0140	0.1168	0.0110	1709	
Z9.1	612	168	0.28	222	64	0.0003	0.00093	0.0964	0.0382	5.4236	0.8914	0.3491	0.0220	0.1127	0.0162	1930	
Z9.2	1459	449	0.32	502	4	1E-05	0.00001	0.0590	0.0269	5.6701	0.5205	0.3391	0.0202	0.1213	0.0076	1882	
Z15	279	17	0.06	104	1	1E-05	0.00001	0.0371	0.0089	6.5028	0.4332	0.3728	0.0158	0.1265	0.0059	2042	
Z5.1	319	62	0.20	129	1	1E-05	0.00001	0.0874	0.0038	7.3016	0.3822	0.3855	0.0158	0.1374	0.0038	2102	
ZM1	158	2	0.01	52	29	0.0006	0.00068	0.0048	0.0274	5.9857	0.6592	0.3342	0.0160	0.1299	0.0121	1859	

¹Uncertainties reported at 1 sigma and are calculated by numerical propagation of all known sources of error.

²Data have been common Pb corrected according to procedures outlined in Stern (1997).

³Concordance = $100 \times (^{208}\text{Pb}/^{238}\text{Pb age}) / (^{207}\text{Pb}/^{235}\text{Pb age})$.

⁴Negative value implies incorrect common Pb

Table 6.2 (continued): SHRIMP analytical data^{1,2}

Labels	$\pm$ age (Ma) $^{206}\text{Pb}/^{238}\text{U}$	AGE (Ma) $^{207}\text{Pb}/^{235}\text{U}$	$\pm$ age (Ma) $^{207}\text{Pb}/^{235}\text{U}$	AGE (Ma) $^{207}\text{Pb}/^{206}\text{Pb}$	$\pm$ age (Ma) $^{207}\text{Pb}/^{206}\text{Pb}$	% Conc ³
Z14	113	2062	74	2084	74	97.9
Z4.2	70	2239	41	2281	34	96.2
Z4.1R	213	1881	155	1915	173	96.6
Z16	91	1912	82	1781	132	114.3
Z6	71	2182	47	2131	56	105.0
Z13	76	1962	75	2041	117	92.5
Z7	68	2074	37	1966	27	111.1
ZA1	70	1801	97	1908	180	89.6
Z9.1	106	1889	152	1843	287	104.7
Z9.2	98	1927	83	1975	116	95.3
Z15	75	2046	60	2050	84	99.6
Z5.1	74	2149	48	2194	49	95.8
ZM1	78	1974	101	2097	174	88.7

¹Uncertainties reported at 1 sigma and are calculated by numerical propagation of all known sources of error.

²Data have been common Pb corrected according to procedures outlined in Stern (1997).

³Concordance = $100 \times (^{206}\text{Pb}/^{238}\text{Pb age}) / (^{207}\text{Pb}/^{206}\text{Pb age})$.

CHAPTER SEVEN: DISCUSSION AND CONCLUSIONS

FIGURES

Figure 7-1: M1 and M2 cooling path calculated for the Nowyak complex

CHAPTER SEVEN: DISCUSSION AND CONCLUSIONS

7.1 Introduction

Preliminary geochronology within the Western Churchill NATMAP region has revealed a complex polymetamorphic history, with tectonothermal events at ca. 2.57, 2.50, 1.91, 1.83, and 1.75 Ga. Interpretation of the tectonic significance of these events is hampered by the limited recognition of structures associated with crustal thickening or exhumation, and by the lack of cooling constraints associated with high-pressure metamorphic events. This project examines the conditions and timing of metamorphism with respect to deformation within the Nowyak complex, a potentially important extensional domain within the Western Churchill Province.

This study was undertaken in order to further constrain the tectonic significance of the Nowyak Complex, and to test the hypothesis that it may represent a metamorphic core complex (Labelle, 1997). An emphasis was placed on determining the timing and sense of displacement of the Nowyak shear zone, defining quantitative pressure and temperatures of metamorphic assemblages in the Nowyak complex and surrounding rocks, and attempting to resolve the apparent contradiction between syn-deformational emplacement of the Nowyak metagranite at ca. 2.64 Ga (zircon and titanite; MacLachlan et al., in preparation, 2001) and ca. 1.82 Ga monazite and possibly garnet growth (Berman, personal communication, 2000). Results should help to elucidate between Archean and Proterozoic metamorphic and deformational events throughout the Western Churchill Province.

7.2 Summary

The Nowyak complex is located within the southern part of the Yathkyed Lake greenstone belt (Figure 2-2), within the northern Hearne province. It is a domain of mid-amphibolite facies rocks exposed in the core of a structural antiform, and is bounded on all but the south side by the ductile, top-down-to-the-north, Nowyak shear zone. A large-scale, northward-trending, upright open fold deformed the Nowyak complex, and post-dated (S_{my}) deformation along the Nowyak shear zone.

7.2.1 Rocks north of the Nowyak complex

Hanging wall rocks include rocks of the Yathkyed and Kaminak Lake greenstone belts, the contact of which is overlain by the Hurwitz Group. The main fabric within both greenstone belts is defined by the alignment of metamorphic minerals, though it is unclear whether S_{main} within the Yathkyed Lake greenstone belt is correlative with S_{main} in the Kaminak Lake greenstone belt (Chapter 4).

Within the northern portion of the Yathkyed Lake greenstone belt, typical mineral assemblages in mafic rocks north of the hornblende-in isograd include hornblende + garnet and hornblende + garnet + epidote (Relf et al., 1998). Hornblende-plagioclase thermometry from one amphibolite yielded a temperature of 745 ± 25 °C, similar to the ~7-8 kbar/750 °C P-T conditions (Chapter 5) calculated by Berman (2000) for metapelites. South of the hornblende-in isograd, typical mineral assemblages contain plagioclase + quartz + actinolite, with hornblende, epidote, and chlorite. This is interpreted to reflect transition from greenschist to amphibole-greenschist grade metamorphism. Hornblende-plagioclase thermometry for two samples, located

approximately 12 km north of the Nowyak shear zone, yielded 580 ± 30 °C and 590 ± 40 °C (Chapter 5), suggesting that these areas did not experience greenschist retrograde metamorphism. However, mapping and thin section petrography for hanging-wall samples located immediately adjacent to the Nowyak complex indicate that the majority of the Yathkyed greenstone belt south of the hornblende-in isograd is at greenschist facies, suggesting that the two samples analysed likely reflect local variations in metamorphic grade. Similar to the Yathkyed and Kaminak Lake greenstone belts, the Hurwitz Group records very low-grade thermal overprinting (Relf et al., 1997) adjacent to the Nowyak complex (Chapter 5).

7.2.2 Nowyak complex

The Nowyak complex lies within the footwall of the Nowyak shear zone, and consists of rocks that display a shallowly north-plunging, penetrative, mineral and stretching lineation that also occurs within the Nowyak shear zone, but is absent within the rocks of the hanging wall. Rocks types include the Nowyak metagranite and minor biotite-muscovite schist located immediately adjacent to the Nowyak shear zone. Within the ca. 2.64 Ga metagranite (MacLachlan et al., in preparation, 2001), two enclaves of the Stonecutter supracrustal unit consist of interlayered psammitic to pelitic schist and garnet amphibolite to gneiss. Within all units, the main S_m fabric within footwall rocks is defined by both the orientation of platy minerals and the orientation of compositional layering. In general, the foliation varies systematically in orientation from west to east; in the NW the foliation strikes $\sim 250^\circ$ and dips moderately to the NW, whereas in the NE,

the foliation strikes $\sim 340^\circ$ and dips moderately to the NE. Stretching lineations trend $\sim 340^\circ$ (Chapter 4).

The Nowyak complex preserves evidence for two metamorphism events: M1 and M2 (Chapter 5). Garnet in both garnet amphibolite and pelitic schist generally displays the following core to rim compositional differences, interpreted to reflect prograde growth zonation: decreasing X_{Sp} , decreasing $Fe/(Fe+Mg)$, and increasing X_{Grs} . The peak metamorphic mineral assemblage in garnet amphibolite includes garnet, hornblende, plagioclase, epidote, and quartz. S_m , the orientation of the platy minerals, envelopes garnet porphyroblasts, while quartz and plagioclase inclusion trails within garnet porphyroblasts lie parallel to and are continuous with S_m . This is interpreted to indicate syn- S_m garnet growth. Biotite grains generally lie at an oblique angle to S_m , indicating post S_m metamorphic growth, and are not considered to be in equilibrium with the main mineral assemblage. Peak metamorphism within garnet amphibolites occurred at $\sim 660^\circ$ C and 12.4 kbar (Chapter 5).

Within pelitic schist, the peak metamorphic assemblage includes kyanite, muscovite, biotite, plagioclase, and quartz. The S_m fabric, defined by the orientation of the platy minerals, envelops the garnet porphyroblasts. A weakly developed S_{m+1} is defined by the crenulation of the S_m fabric. Garnet growth is interpreted to be syn- S_m , based on the occurrence within garnet porphyroblasts of curved and straight inclusion trails of plagioclase, biotite, and quartz that can commonly be traced into the matrix. Based on compositional data and geothermobarometric calculations, peak metamorphism within pelitic schists occurred at $\sim 660^\circ$ C and 11.8 kbar.

Geothermobarometry on garnet amphibolite and pelitic schist samples from the Stonecutter supracrustal unit gives a clockwise M1 P-T-t path (Figure 5-40), consistent with garnet growth during crustal thickening to depths of 40 km, followed by denudation and exhumation. The effects of a second metamorphic event, M2, are best recorded in pelite samples that display breakdown of garnet to intergrowths of randomly-oriented biotite, plagioclase, muscovite and quartz. A marked decrease in X_{Grs} of garnet occurs locally within fractures in the garnet and at the extreme outer rim, and is correlated with an increase in X_{An} of adjacent plagioclase. M2 occurred at approximately 565 °C and 6.1 kbar (Chapter 5).

The age of the Stonecutter supracrustal unit is ambiguous. Zircon fractions separated from a biotite-kyanite-muscovite-garnet pelitic schist within the unit do not appear to define a discordia curve, nor do they cluster around one age. The best $^{207}\text{Pb}/^{206}\text{Pb}$ ages are given by near-concordant analyses, with small associated errors and little to no common Pb. These range in age from 1780 ± 132 Ma (1σ) to 2194 ± 49 Ma (1σ ; Figure 6-5). Relatively high Th/U ratios (0.01 to 0.49) and evidence of primary zoning strongly suggest that analyzed grains are detrital with an igneous provenance, and not metamorphic. The zircon analysis may either represent: (1) primary igneous ages, which would suggest that the Stonecutter supracrustal unit is Proterozoic in age, or (2) Archean ages that have been partially reset during the Proterozoic, which would indicate that the Stonecutter supracrustal unit is Archean in age (Chapter 6). If the zircons were not reset, then the maximum age of the Stonecutter supracrustal unit is 1966 ± 53 (1σ) Ma, the age of the youngest zircon fraction.

Ca. 1820 Ma monazite, dated by in-situ ion probe analysis of a biotite-muscovite-garnet pelitic schist within the Stonecutter supracrustal unit by Berman et al. (2000), appear to be syn-kinematic with respect to the main S_m fabric, and suggesting that the timing of the M1 metamorphic event is ca. 1.82 Ma. Alternatively, M1 may have occurred at ca. 1.90 Ma, the age of high-pressure metamorphism recorded elsewhere in the northern Hearne domain, with the ca. 1.82 Ga foliation-parallel monazite growing during concordant reactivation of the (S_m) foliation.

^{40}Ar - ^{39}Ar data yield plateau dates of ca. 1775-1804 Ma for hornblende, ca. 1748-1746 Ma for muscovite, and ca. 1760-1741 Ma for biotite (Figure 6-2), similar to ages calculated outside of the complex within the Kaminak and Yathkyed Lake greenstone belts. These data indicate that the rocks cooled through 500 °C, the closure temperature of hornblende, between ca. 1775 - 1800 Ma. This cooling post-dates the intrusion of ca. 1.85-1.81 Ga Hudsonian granitoids, of which one large pluton is located immediately south of the Nowyak complex (Peterson, personal communication, 2001). Biotite and muscovite ages overlap, within error, and are interpreted to indicate rapid cooling at ca. 1750 Ma, through the muscovite and biotite closure temperatures at 350 °C and 280 °C, respectively (Chapter 6).

7.2.3 Nowyak shear zone

Within the ductile Nowyak shear zone, the dominant S_{my} foliation is interpreted to be a shear foliation, and is defined by moderately-dipping C-planes. S_{my} is concordant to S_m within footwall rocks (Chapter 4). Down-dip extension lineations and north-side down kinematic indicators preserved on the north, northwest, and northeast sides of the

Nowyak shear zone suggest either a normal fault, or an arched thrust fault. It is difficult to distinguish between the two models just from local geology. Regionally, a thrust fault would root to the south and reappear north of the complex. Such a structure has not been mapped in the Nowyak Lake area. Evidence for Paleoproterozoic extension has been documented in the Tyrrell shear zone north of the Nowyak complex, but regional correlations have yet to be completed in order to kinematically link these domains to that of the Nowyak complex. Extension along the Nowyak shear zone allows for juxtaposition of mid-amphibolite facies footwall rocks immediately adjacent to greenschist-facies hanging wall rocks.

Footwall and shear zone rocks preserve two sets of folds. F_{my-1} are relict, pre- S_{my} minor folds which have not been related to map-scale structures. F_{my+1} (shear zone) and F_{m+1} (footwall) fold S_{my} and S_m , respectively. Stereonet projections of poles to foliations are dispersed about a great circle, and lineations disperse about a small circle. Although these data are consistent with folding of the shear zone after its development (Figure 4-4), a larger data set is needed to substantiate this. The calculated large-scale map fold calculated is identical in orientation to F_{my+1} and F_{m+1} folds mapped in outcrop ($\sim 06^\circ/021^\circ$).

The Nowyak shear zone is at greenschist facies, and contains a typical mineral assemblage of chlorite + quartz + plagioclase $\pm$ actinolite $\pm$ hornblende $\pm$ opaques $\pm$ epidote. Thermometry, calculated from amphibolite enclaves located within the shear zone, gives temperatures ranging from $545 \pm 15^\circ\text{C}$ to $650 \pm 20^\circ\text{C}$ for core analysis and $590 \pm 10^\circ\text{C}$ to $640 \pm 20^\circ\text{C}$ for rim analysis, with an average temperature of $615 \pm 55^\circ\text{C}$.

(Chapter 5). This temperature likely reflects metamorphic conditions prior to greenschist-facies retrograde metamorphism.

It is difficult to determine the age constraints of deformation along the Nowyak shear zone, as no datable material is present in the area (e.g. deformational and cross-cutting dykes). A sense of when deformation may have occurred is given by considering textural evidence for the timing of M1 and M2 metamorphism, with respect to S_m and S_{my} foliation development and ^{40}Ar - ^{39}Ar cooling ages.

The Nowyak shear zone includes a Proterozoic Hurwitz Group enclave, interpreted by Relf et al (1997) to be correlative to the Watterson Group. Aspler and Chiarenzelli (in press, 2000) interpret the Watterson and the Tavani formation to be part of a single fluvial to mixed siliciclastic-carbonate ramp depositional system. The youngest detrital zircon, dated at 1907 ± 27 Ma, establishes the maximum age limit for the two units. Thus, the Nowyak shear zone likely experienced motion post-ca. 1907 Ma (Chapter 3).

Petrographic observations indicate that garnet breakdown during M2 (565 °C/6.1 kbar) metamorphism overprints the S_m foliation. Assuming S_m is correlative with S_{my} , and that M2 is related to the intrusion of the 1.85 - 1.81 Ga Hudsonian granites as suggested by hornblende ^{40}Ar - ^{39}Ar cooling ages, which range from 1.80 - 1.78 Ga, S_{my} is interpreted to have formed prior to ca. 1.81 Ga (Chapter 6).

Shear zone movement between 1.83 – 1.90 Ga has been documented within the Yathkyed Lake greenstone belt, north of the Nowyak complex. MacLachlan et al. (2000) documented 2 episodes of movement along the Tyrrell shear zone: ca. 2620 Ma oblique

reverse displacement and ca. 1810 Ma oblique dextral-normal movement. MacLachlan et al. project the Tyrrell shear zone southwards along strike, and suggest that the Nowyak shear zone may be a splay of the Tyrrell shear zone (though it should be noted that no kinematic studies have been done relating the two shear zones). MacLachlan et al. (2000) suggest that if the Nowyak shear zone is kinematically linked to the Tyrrell shear zone, it may not be unreasonable to assume that the two shear zones may have experienced similar histories.

7.3 Relative role of Archean and Proterozoic events

Data collected in this thesis are used to evaluate the relative roles of Archean and Proterozoic events within the Nowyak complex. Proterozoic ^{40}Ar - ^{39}Ar hornblende ages and U-Pb zircon and monazite geochronology from the Nowyak complex suggest a thermal event at ca. 1775 - 1804 Ma, negating the possibility of an exclusively Archean history. This leaves two main tectonic models for development of the Nowyak complex; it either records solely Proterozoic history, or it records an Archean history with a Proterozoic overprint. The key to discrimination between them is in the way in which U-Pb zircon geochronology from the Stonecutter supracrustal unit, and Archean zircon and titanite ages from the Nowyak metagranite are interpreted.

7.3.1 Proterozoic history

There are three lines of reasoning that indicate that the Nowyak complex underwent a significant thermal and deformational event during the Proterozoic. Ca. 2.45 Ga to 1.91 Ga Watterson Group sediments (Aspler and Chiarenzelli, in press, 2000), interpreted to be incorporated in the Nowyak shear zone (Relf et al., 1997) indicate that

metamorphism and exhumation of the Nowyak complex must have occurred after the deposition of the youngest part of the Hurwitz Group. This is supported by U-Pb SHRIMP geochronology on zircons and monazites from the Stonecutter supracrustal unit, which show moderate Th/U ratios and evidence of primary igneous textures (e.g. oscillatory zoning). They are interpreted to be magmatic in origin, and were deposited as detritus in the Stonecutter supracrustal unit. The age of the youngest zircon constrains both the timing of Stonecutter deposition, and the upper-time limit of high-pressure metamorphism (M1) to be 1966 ± 53 Ma (1σ). Ca. 1.82 Ga monazite within the Stonecutter supracrustal unit (Berman et al., 2000) is interpreted to be syn-kinematic with respect to the main S_m fabric, lending credence to the suggestion that M1 is Proterozoic in age.

M2 crosscuts the S_m foliation, and has been tentatively correlated with the intrusion of the Hudsonian granites (ca. 1.81 Ga - 1.85 Ma; Peterson et al., 2000). ^{40}Ar - ^{39}Ar Proterozoic cooling ages, ranging in age from ca. 1775 to 1804 Ma, 1746 to 1748 Ma, and 1740 to 1780 Ma for hornblende, biotite, and muscovite, respectively, may reflect late-stage M2 cooling from 500 °C - 280 °C.

The exact timing for both the M1 and the M2 metamorphic events remains ambiguous. M1 and M2 may be part of the same metamorphic event (e.g. two phases of one prolonged thermal event), or they may be two separate thermal events. M1 occurred at 660 °C/12 kbar, whereas M2 occurred at 565 °C/6.1 kbar (Figure 7-1). U-Pb geochronology for monazite is the same, within error, as ^{40}Ar - ^{39}Ar hornblende cooling ages, allowing for the possibility that M1 and M2 are related to the same thermal event.

If this is the case, it would indicate a exhumation of ~ 18 km associated with only 100 °C cooling, suggesting nearly isothermal decompression of the Nowyak complex at ca. 1.82 Ga.

The geometry and metamorphic history of the Nowyak complex is compatible with the interpretation that it is a metamorphic core complex. However, if cooling of the complex was affected by extensional denudation, then one would expect that ^{40}Ar - ^{39}Ar ages from the footwall to be younger than that of the surrounding complex. Preliminary data indicate that this may not be case, as hornblende cooling ages are the same within error. It should be noted, though, that these ages may reflect resetting at a later time (e.g. during intrusion of the ca. 1.75 Nueltin granites; Peterson, 2000). In this case, the argon data would be unsuitable for defining the cooling history related to denudation.

7.3.2 Archean history

An Archean deformation event is interpreted to have occurred in the variably deformed Nowyak metagranite at ca. 2.64 Ga by MacLachlan et al. (2001, in preparation). Zircon and titanites cluster near the upper intercept on a discordia chord that passes through the origin, with no evidence in the U-Pb systematics to indicate Proterozoic disturbance. Therefore, MacLachlan et al. (in preparation, 2001) interpret the major deformation and metamorphic event in the Nowyak complex to be ca. 2.64 Ga in age.

In contrast, the results of this study indicate the Nowyak complex experienced Proterozoic deformation and metamorphism (see arguments in previous section) It is difficult to reconcile preservation of Archean U-Pb systematics in the light of ca. 1.82 Ga monazite growth, M1 metamorphic conditions at 660 °C/12 kbar, and the amount of

penetrative deformation observed throughout the Nowyak metagranite. There are two possible solutions to this problem. There may be a problem with the interpretation of one or more of the data sets. For example, the Stonecutter supracrustal unit may in fact be Archean in age.

The preferred explanation, however, is that Proterozoic metamorphism did not reset U-Pb systematics. There are a number of possible explanations: (1) the Nowyak metagranite may be a composite pluton, recording both Archean and Proterozoic magmatic phases. In this case, Proterozoic strain and metamorphism may be partitioned within the Nowyak metagranite, and the sample analysed for U-Pb geochronology may have been located within an enclave that escaped Proterozoic deformation and metamorphism; (2) the M1 metamorphic event occurred below titanite closure temperatures (660 - 700 °C; Scott and St. Onge, 1995). Evidence of titanite and zircon grains surviving high-grade metamorphic (>> 670 °C) with little to no resetting of their chemical systematics is documented by Parrish (in preparation, 2001) and Krogh et al. (1988). Moreover, although peak metamorphic conditions are similar to the above estimate of titanite closure temperature, the higher structural position of the geochronological sample relative to the thermobarometry samples indicates that it is likely that the geochronological sample experienced temperatures less than ~650 °C. (3) Proterozoic deformation may not have affected the radiogenic Pb budget within zircons and titanites of the Nowyak metagranite, allowing the 2.64 Ga granite to experience later deformation without resetting zircon and titanite systematics, as documented elsewhere by Parrish (in preparation, 2001) and Krogh et al. (1988); or (4) the contact between the

metagranite and the Stonecutter supracrustal unit may be a discrete cryptic fault separating rocks with completely different histories.

6.4 Tectonic models

The results of this thesis clearly indicate that the Nowyak complex has an Archean igneous ($\pm$ deformational) history that was strongly affected by a Proterozoic event. The preferred history is: (1) the Nowyak granite intruded ($\pm$ deformed) at ca. 2.64 Ga (MacLachlan et al., in preparation, 2001), (2) deposition of the Stonecutter supracrustal unit occurred at or after ca. 1966 ± 53 Ma (1σ) (Chapter 6), (3) final deposition of the stable Hurwitz basin occurred at ca. 1.91 Ga, the age of the youngest member Hurwitz Group (Aspler and Chiarenzelli, in press, 2000), (4) burial and metamorphism (M1) of the Nowyak complex at ca. 1.82 Ga (Chapter 5), and (5) exhumation and decompression of the Nowyak complex, likely related to movement along the Nowyak shear zone, was accompanied by granite emplacement (Hudsonian granites) and the M2 metamorphic event. The data permit M1 and M2 to be part of one metamorphic event, though it is not required. If they are not part of the same event, then #4 could occur before #3 (above). ^{40}Ar - ^{39}Ar cooling ages indicate that no major thermal events occurred post ca. 1.75 Ga (Chapter 6). The above scenario is consistent with known data, however, other tectonic interpretations may also fit with this data. Further work is required in order to fully understand the tectonometamorphic history of the Nowyak complex.

7.5 Suggestions for further work

Questions still remain regarding the relative roles of Archean and Proterozoic deformation. Further studies should be carried out to refine the timing of deformation.

Where present, deformed and cross-cutting dykes within the shear zone should be dated in order to bracket the time of deformation. A detailed kinematic study should be completed for the shear zone, with a special emphasis on the western side which has little kinematic data, in order to test two tectonic models for the Nowyak complex: a shear-fold model, as proposed in the current study, or a metamorphic core complex, suggested by Labelle (1997). Further ^{40}Ar - ^{39}Ar work should be completed in order to better characterize the cooling history of hanging wall rocks near the Nowyak shear zone with respect to that documented within the Nowyak complex.

U-Pb geochronology should be completed via conventional U/Pb techniques (e.g. ID-TIMS) in order to better constrain the age of the Stonecutter supracrustal unit (Archean vs. Proterozoic), and to get a sense of whether it represents a tectonic slice, a sedimentary outlier, or a raft within the metagranite. Targeted monazite SHRIMP studies should be completed on monazites in order to get a better constraint on the timing of M1 metamorphism, and titanite should be analysed from the garnet amphibolite. The Nowyak metagranite should be examined in order to determine whether Proterozoic strain and M1 metamorphism may be partitioned throughout the pluton, or whether the metagranite may be a composite pluton.

Finally, the Nowyak complex should be mapped southwards of its present boundary.

Figure 7-1: Nowyak cooling path, assuming M1 and M2 belong to the same thermal event (~16 °C/kbar). Abbreviations from Kretz (1983).

REFERENCES

- Armstrong, J.T., 1988. Quantitative analysis of silicates and oxide minerals: Comparison of Monte-Carlo, ZAF, and Phi-Rho-Z procedures. *Microbeam Analysis*: 239 - 246.
- Ashton, K., Hartlaub, R.P., Heaman, L.M., and Card, C.C., 2000. The northeastern Rae province in northern Saskatchewan. Geological Association of Canada Annual Meeting, Program with Abstracts, 25; on CD-ROM.
- Aspler, L.B., and Chiarenzelli, J.R., 1996. Geological compilation of the Hearne Province, southern-central District of Keewatin. Department of Indian Affairs and Development, Geology Division EGS 1996-2.
- Aspler, L.B., and Chiarenzelli, J.R., 1996. Stratigraphy, sedimentation, and physical volcanology of the Ennadai-Rankin greenstone belt, Northwest Territories, Canada: Late Archean paleogeography of the Hearne province and tectonic implications. *Precambrian Research*, 77: 59 - 89.
- Aspler, L.B., and Chiarenzelli, J.R., 1997. Initiation of ca. 2.45 - 2.1 Ga intracratonic basin sedimentation of the Hurwitz Group, Keewatin Hinterland, Northwest Territories, Canada. *Precambrian Research*, 81: 265 - 297.
- Aspler, L.B., and Chiarenzelli, J.R., 2000. Mixed siliclastic-carbonate storm-dominated ramp in a rejuvenated Paleoproterozoic intracratonic basin: upper Hurwitz Group, Nunavut, Canada. *Submitted to Precambrian Sedimentary Environments, International Association of Sedimentologists Special Publication*.
- Aspler, L.B., Bursey, T.L., and Miller, A.R., 1989. Sedimentology, structure, and economic geology of Poorfish-Windy thrust-fold belt, Ennadai Lake area, District of Keewatin, and shelf to foreland transition in the foreland of Trans of Trans Hudson Orogen. *In Current Research, Part C, Geological Survey of Canada, Paper 89-1C*: 143 - 155.
- Baldwin, J., and Bowring, S., 2000. U-Pb geochronological constraints on the nature and timing of high-grade metamorphism in the Striding-Athabasca mylonite zone, northern Saskatchewan, Canada. Geological Association of Canada Annual Meeting, Program with Abstracts, 25; on CD-ROM.
- Barker, A.J., 1990. Introduction to metamorphic textures and microstructures. Chapman and Hall, New York, United States of America: 162 pp.
- Bell, T.H., 1985. Deformation partitioning and porphyroblast rotation in metamorphic rocks: a radical interpretation. *Journal of Petrography*, 3: 267 - 286.

- Berman, R.G., 1990. Mixing properties of Ca-Mg-Fe-Mn garnets. *American Mineralogist*, **75**: 328 - 344.
- Berman, R.G., 1991. Thermobarometry using multi-equilibrium calculations: a new technique, with petrological applications. *Canadian Mineralogist*, **29**: 833 - 855.
- Berman, R., Ryan, J.J., Tella, S., Sanborn-Barrie, M., Stern, R., Aspler, A., Hanmer, S., and Davis, W.J., 2000. The case of multiple metamorphic events in the Western Churchill province: evidence from linked thermobarometric and in-situ SHRIMP data, and jury deliberations. Geological Association of Canada Annual Meeting, Program with Abstracts, **25**; on CD-ROM.
- Bickford, M.E., Collerson, K.D., and Lewry, J.F., 1994. Crustal history of the Rae and Hearne provinces, southwestern Canadian Shield, Saskatchewan: constraints from geochronologic and isotopic data. *Precambrian Research*, **68**: 1 - 21.
- Carolan, J., Crocker, C.H., and Collerson, K.D., 1989. Structural relationships of the Western Granulite domain and the Virgin River Shear Zone. *In* Summary of Investigations 1989, Saskatchewan Energy of Mines, Miscellaneous Reports: **89-4**: 102 - 104.
- Cherniak, D.J., Hanchar, J.M., and Watson, E.B., 1997. Rare-earth diffusion in zircon. *Chemical Geology*, **134**: 289-301.
- Crocker, C.H., Collerson, K.D., Lewry, J.F., and Bickford, M.E., 1993. Sm-Nd, U-Pb, and Rb-Sr geochronology and lithostructural relationships in the southwestern Rae province: constraints on crustal assembly in the western Canadian shield. *Precambrian Research*, **61**: 27 - 50.
- Cumming, G.L., and Richards, J.R., 1975. Ore lead isotopes in a continuously changing earth. *Earth and Planetary Science Letters*, **28**: 155-171.
- Davidson, A., 1970. Precambrian geology, Kaminak Lake map-area, District of Keewatin (55L). Geological Survey of Canada, Paper 69-51: 27p.
- Davidson, A., Carmichael, D.M., Pattison, D.R.M., 1990., Field guide to the metamorphism and geodynamics in the southwestern Grenville province, Ontario. International Geological Correlation program, 123 p.
- Davis, W.J., 2000. Regional differences in the Neoarchean crustal evolution of the Western Churchill province: Can we make sense of it? Geological Association of Canada Annual Meeting, Program with Abstracts, **25**; on CD-ROM.

- Davis, W.J., Aspler, L.B., and Rainbird, R.H., 2001 (in preparation). Potential significance of late Neoarchean to Paleoproterozoic siliciclastic sequences, Hearne domain, Western Churchill province, Canada.
- Davis, W.J., Aspler, L.B., Rainbird, R.H., and Chiarenzelli, J.R., 2000. Detrital zircon geochronology of the Proterozoic Hurwitz and Kiyuk groups: a revised post-1.92 Ga age for deposition of the upper Hurwitz Group. Geological Association of Canada Annual Meeting, Program with Abstracts, 25; on CD-ROM.
- Davis, W.J., Hanmer, S., Aspler, L.B., Sandeman, H., Tella, S., Zaleski, E., Relf, C., Ryan, J., Berman, R., and MacLachlan, K., 2000. Regional differences in the Neoarchean crustal evolution of the Western Churchill province: can we make sense of it? Geological Association of Canada Annual Meeting, Program with abstracts, 25; online @ <http://www.geocanada2000>.
- Eade, K.E., 1974. Geology, Kognak River area, District of Keewatin, Northwest Territories. Geological Survey of Canada Memoir 377.
- Eade, K.E., 1986. Precambrian geology of the Tulemalu Lake - Yathkyed Lake area, District of Keewatin. Geological Survey of Canada, Paper 84-11, 31 p.
- Florence, F.P and Spear, F.S., 1991. Effects of diffusional modification of garnet growth zoning on P-T path calculations. Contributions to Mineralogy and Petrology, 107: 487 - 500.
- Fuhrman, M.L., and Lindsley, D.H., 1988. Ternary - feldspar modeling and thermometry. The American Mineralogist, 73: 201 - 216.
- Faure, G., 1986. Principle of isotope geology, second edition. John Wiley and Sons.
- Jones, A., Snyder, D., Asudeh, I., White, D., Eaton, D., and Clarke, G., 2000. Lithospheric architecture at the Rae-Hearne boundary revealed through magnetotelluric and seismic experiments. Geological Association of Canada Annual Meeting, Program with Abstracts, 25; on CD-ROM.
- Labelle, A., 1997. Structural and metamorphic history of the Nowyak shear zone, Western Churchill Province. NWT. Unpublished B.Sc. thesis, Carleton University.
- Lewry, J.F., and Collerson, K.D., 1990. The Trans-Hudson orogen: extent, subdivision, and problems. Geological Association of Canada, Special paper 37: 1 - 14.

- Lewry, J.F., and Sibbald, T., 1977., Variation in lithology and tectonometamorphic relationships in the Precambrian basement of northern Saskatchewan. *Canadian Journal of Earth Sciences*, 14: 1453 - 1467.
- Lewry, J.F., Sibbald, T., and Schledewitz, D.C.P., 1985. Variation in character of Archean rocks in the Western Churchill province and its significance. *In* Evolution of Archean supracrustal sequences. *Edited by* L.D. Ayres, P.C. Thurston, K.D. Card, and W. Weber. Geological Society of Canada, Special paper 28: 239 - 261.
- Hanchar, J.M., and Miller, C.F., 1993. Zircon zonation patterns as revealed by cathodoluminescence and backscattered electron images: implications for interpretation of complex crustal histories. *Chemical Geology*, 110: 1 - 13.
- Hanmer, S., 1997. Geology of the Striding-Athabasca mylonite zone, northern Saskatchewan and southeastern district of Mackenzie, Northwest Territories. Geological Survey of Canada Bulletin 501, 87 p.
- Hanmer, S., Aspler, L., Sandeman, H., Davis, W.J., Peterson, T., Relf, C., Ryan, J., and Roest, W., 2000. Henik-Kaminak-Tavani supracrustal belt, late Archean oceanic crust and island arc remnants; upper crust protected from Proterozoic reworking. Geological Association of Canada Annual Meeting, Program with Abstracts, 25; on CD-ROM.
- Hanmer, S., Cheng, J., Darrach, M., and Kopf, C., 1990. The Snowbird Tectonic Zone, Stoney Rapids area, northern Saskatchewan. *In* Summary of Investigations, 1990, Saskatchewan Geological Survey, Saskatchewan Energy and Mines, Miscellaneous Report 1991-4: 192-195.
- Hanmer, S., Darrach, M., and Kopf, C., 1992. The East Athabasca mylonite zone: an Archean segment of the Snowbird tectonic zone in northern Saskatchewan. *In* Current Research, Part C; Geological Survey of Canada, Paper 92-1C: 19-29.
- Hanmer, S., Sandeman, H., Davis, W.J., Aspler, L., Rainbird, R.H., Peterson, T., Ryan, J., Roest, W., Relf, C., and Irwin, D., 2001 (in preparation). Tectonic setting of the Neoarchean Henik-Kaminak-Tavani greenstone belt, Western Churchill province, Canada: a geological perspective.
- Hanmer, S., Shaocheng, J., Darrach, M., and Kopf, C., 1991. Tantato domain, northern Saskatchewan: a segment of the Snowbird tectonic zone. *In* Current Research, Part C; Geological Survey of Canada, Paper 91-1C: 121-133.
- Hanmer, S., Tella, S., Sandeman, H.A., Ryan, J.J., Hadlari, T., and Mills, A., 1999. Proterozoic reworking in Western Churchill province, Gibson Lake - Cross Bay

- area, Northwest Territories (Kivalliq region), Nunavut. *In* Current Research, Part C, Geological Survey of Canada, Paper 99-1C: 55 - 64.
- Hanmer, S., Williams, M., and Kopf, C., 1995. Striding-Athabasca mylonite zone: implications for the Archean and early Proterozoic tectonics of the western Canadian shield. *Canadian Journal of Earth Sciences*, 32: 178-196.
- Heaman, L.M., and Rudnick, R.L., 1999. The chemical composition of igneous zircon suites: implications for geochemical tracer studies. *Geochimica et Cosmochimica Acta*, 62, No. 14: 2509-2520.
- Hoffman, P.F., 1988. United plates of America, the birth of a continent: Early Proterozoic assembly and growth of Laurentia. *Annual Review of Earth Planet Science*, 16: 543 - 603.
- Hoffman, P.F., 1990. Subdivision of the Churchill province and extent of the Trans-Hudson orogen. *In* J.F. Lewry and M.R. Stauffer (Editors), *The Proterozoic Trans-Hudson orogen of North America*. Geological Society of Canada, Special paper 37: 15 - 39.
- Holland, T., and Blundy, J., 1994. Non-ideal interactions in calcic amphiboles and their bearing on amphibole-plagioclase thermometry. *Contributions to Mineral Petrology*, 116: 433-447.
- Kretz, R., 1983. Symbols for rock-forming minerals. *American Mineralogist*, 68: 277 - 279.
- Labelle, A., 1997. Structural and metamorphic history of the Nowyak shear zone, Western Churchill province, Northwest Territories. Carleton University B.Sc. thesis: 56 p.
- Lee, J.K., Williams, I.S., and Ellis, D.J., 1997. Pb, U, and Th diffusion in natural zircon. *Nature*, 390: 159 - 161.
- Lewry, J.F., and Sibbald, T.I.L., 1977. Variation in lithology and thermotectonic relations in the Precambrian basement of northern Saskatchewan. *Canadian Journal of Earth Sciences*, 14: 1453-1467.
- Lewry, J.F., Sibbald, T.I.L., and Schledewitz, D.C.P., 1985. Variation in character of Archean rocks in the Western Churchill province and its significance. *In* L.D. Ayers, P.C. Thurston, K.D. Card and W. Weber (Editors), *Evolution of Archean Supracrustal Sequences*, Geological Society of Canada Special Paper 28: 239-261.
- Lord, C.S., 1953. Geological notes on southern District of Keewatin, Northwest Territories. Geological Survey of Canada, Paper 53 - 22.

- Loveridge, W.D., Eade, K.E., and Sullivan, R.W., 1988. Geochronological studies of Precambrian rocks from the southern District of Keewatin. Geological Survey of Canada, Paper 88-18, 36p.
- Mader, U.K., Percival J.A., and Berman R.G., 1994. Thermobarometry of garnet-clinopyroxene-hornblende granulites from the Kapuskasing structural zone. *Canadian Journal of Earth Sciences*, 31: 1134-1145.
- MacLachlan, K., 2000. Complex, protracted, Proterozoic reworking of the Western Churchill province: the craton that wouldn't grow up?. Geological Association of Canada Annual Meeting, Program with Abstracts, 25; on CD-ROM.
- MacLachlan, K., Relf, C., and Davis, W.J., 2000. U/Pb geochronological constraints on structures controlling distribution of tectonothermal domains, Yathkyed Lake area, Western Churchill province. Geological Association of Canada Annual Meeting, Program with Abstracts, 25; online @ <http://www.geocanada.com>.
- MacLachlan, K., Relf, C., and Davis, B., 2001 (in preparation). U/Pb geochronological constraints on Archean amalgamation and Proterozoic reworking, Yathkyed greenstone belt, Western Churchill province.
- McDougall, I., and Harrison, T.M., 1999. Geochronology and thermochronology by the $^{40}\text{Ar}/^{39}\text{Ar}$ method. Oxford Monographs on Geology and Geophysics No. 9, Oxford University Press, New York.
- McMullin, D., Berman, R.G., and Greenwood, H.J., 1991. Calibration of the SGAM thermobarometer for pelitic rocks using data from phase equilibrium experiments and natural assemblages. *Canadian Mineralogist*, 29: 889 - 908.
- Meldrum, A., Boatner, L.A., Weber, W.J., and Ewing, R.C., 1998. Radiation damage in zircon and monazite. *Geochemica et Cosmochimica Acta*, 62, No.14: 2509 - 2520.
- Menard, T., and Spear, F.S., 1994. Metamorphic P-T paths from calcic pelitic schists from the Strafford Dome, Vermont, USA. *Journal of metamorphic petrology*, 12: 811 - 826.
- Parrish, R., 2001 (in preparation). The response in mineral chronometers to metamorphism and deformation in orogenic belts.
- Passchier, C.W., and Trouw, R.A.J., 1996. Micro-tectonics. Springer-Verlag, New York.

- Peterson, T., van Breeman, O., Sandeman, H., and Rainbird, R., 2000. Proterozoic (1.85 - 1.75 Ga) granitoid plutonism and tectonic of the Western Churchill province. Geological Association of Canada Annual Meeting, Program with Abstracts, 25; on CD-ROM.
- Ramsey, J.G., and Graham, R.H., 1970. Strain variation in shear belts. *Canadian Journal of Earth Sciences*, 7: 786 - 813.
- Relf, C., 1996. Geology of the Nowyak Lake area, parts of NTS 65 G/9, 15, 16, 65 H/13, 65 I/4, and 65 J/1. Department of Resources, Wildlife, and Economic Development, Government of the Northwest Territories.
- Relf, C., and Hanmer, S., 2000. A speculative and critical summary of the current state of knowledge of the Western Churchill province; a NATMAP perspective. Geological Association of Canada Annual Meeting, Program with Abstracts, 25; on CD-ROM.
- Relf, C., Irwin, D., MacLachlan, K., and Mills, A., 1998. New insights into the geology of the Yathkyed Lake greenstone belt, Western Churchill province, Northwest Territories. *In* Current Research, Part C, Geological Survey of Canada, Paper 98-1C: 67 - 75.
- Relf, C., MacLachlan, K., Irwin, D., 1999. Tectonic assembly and Proterozoic reworking of the northern Yathkyed greenstone belt, Northwest Territories (Nunavut). *In* Current Research, Part C, Geological Survey of Canada, Paper 99-1C: 139 - 146.
- Relf, C., Scott, C., Lepine, I., and Labelle, A., 1997. Geology and deformation history of the Nowyak Lake area, Western Churchill province, Northwest Territories. *In* Current Research, Part C, Geological Survey of Canada, Paper 97-C: 71 - 79.
- Reynolds, P.H., 1992. Low temperature thermochronology by the $^{40}\text{Ar}/^{39}\text{Ar}$ method. *In* Low temperature thermochronology. Edited by M. Zentilli and P.H. Reynolds. Mineralogical Association of Canada, Short Course Handbook 20, pp. 3-20.
- Roddick, J.C. and Miller, A.R., 1993. An ^{40}Ar - ^{39}Ar age from the REE-enriched Enetatcha alkaline intrusive suite and implications for timing of ultrapotassic magmatism in the central Churchill Structural Province. *In* Radiometric age and isotope studies: Report 8, Geological Survey of Canada, 1994-F: 69 - 74.
- Ross, G.M., Parrish, R.R., Villeneuve, M.E., and Bowring, S.A., 1991. Geophysics and geochronology of the crystalline basement of the Alberta Basin, western Canada. *Canadian Journal of Earth Science*, 28: 512-522.

- Ross, G.M., Milkereit, B., Eaton, D., White, D., Kanasewich, E.R., and Burianyk, M.J., 1995. Paleoproterozoic collisional orogen beneath the western Canada sedimentary basin imaged by Lithoprobe crustal seismic-reflection data. *Geology*, 23: 195 - 199.
- Sanborn-Barrie, M., 1994. Structural investigation of high-grade metamorphism in the Kramanituar complex, Baker Lake area, Northwest Territories. *In* Current Research, Part C, Geological Survey of Canada, Paper 94-C: 121 - 133.
- Sanborn-Barrie, M., 1999. Geology, geothermobarometry, and geochronology of the high-P granulite-facies Kramanituar Complex, Western Churchill province. Ph.D. Thesis, Carleton University.
- Sandeman, H.A., 2001. ^{40}Ar - ^{39}Ar geochronological investigations in the central Hearne domain, Western Churchill province, Kivalliq Region, Nunavut: a progress report. *Submitted to: Radiogenic and Isotope Studies Reports, Geological Survey of Canada.*
- Sandeman, H.A., 2000. Archean volcanic sequences of the Western Churchill province, Nunavut, Canada: three petrochemically distinct domains of non-plateau affinity. Geological Association of Canada Annual Meeting, Program with Abstracts, 25; on CD-ROM.
- Schaltegger, U., Fanning, C.M., Gunther, D., Maurin, J.C., Schulmann, K., and Gebauer, D., 1999. Growth, annealing and recrystallization of zircon and preservation of monazite in high-grade metamorphism: conventional and in-situ U-Pb isotope, cathodoluminescence and microchemical evidence. *Contributions to Mineralogy Petrology*, 134: 186-201.
- Schau, M., 1982. Geology of the Prince Albert Group in parts of Walker Lake and Laughland Lake map area, District of Keewatin. Geological Survey of Canada Bulletin 1982-1A:143-150.
- Scott, D.J. and St. Onge, M.R., 1995. Constraints on Pb closure in titanite based on rocks from the Ungava orogen, Canada; implications for U-Pb geochronology and P-T-t path determination. *Geology*, 23: 1123-1126.
- Simpson, C., 1985. Deformation of granitic rocks across the brittle-ductile transition. *Journal of Structural Geology*, 7: 502-511.
- Spear, F.S., 1993. Metamorphic phase equilibria and pressure-temperature-time paths. Mineralogical Society of America Monograph. 799 p.

- Spear, F.S., and Kimball, K.L., 1984. RECAMP - A FORTRAN IV program for estimating Fe^{3+} contents in amphiboles. *Computers in Geology*, 10: 317-325.
- Stern, R.A., 1997. The GSC Sensitive High Resolution Ion Microprobe (SHRIMP): analytical techniques of zircon U-Th-Pb age determinations and performance evaluation. *In Radiogenic age and isotope studies: report 10; Geological Survey of Canada, Current Research 1997-F: 1-31.*
- Stern, R.A., and Berman, R., 2000. Monazite U-Pb and Th-Pb geochronology by ion microprobe, with an application to in situ dating of an Archean metasedimentary rock. *Chemical Geology*, 172: 113-130.
- Tella, S., and Eade, K.E., 1980. Geology of the Kamilukuak Lake map area, District of Keewatin, a part of the Churchill Structural Province. *In Current Research 1980-1B: 39-45.*
- Tella, S., and Eade, K.E., 1986. Geology, Kamilukuak Lake map area, District of Keewatin, N.W.T. Geological Survey of Canada, map 1629 A.
- Tella, S., Eade, K.E., Miller, A.R., and Lamontagne, C.G., 1981. Geology of the west-half of the Kamilukuak Lake map area: a part of the Churchill Structural Province. *In Current Research 1983-1A: 403-409.*
- Tella, S., Hanmer, S., Ryan, J., Sandeman, H., Davis, W.J., Berman, R., and Wilkinson, L., 2000. 1:100 000 scale bedrock geology compilation map of the MacQuoid Lake-Gibson Lake-Cross Bay-Akunak Bay region, Western Churchill province, Nunavut, Canada. Geological Association of Canada Annual Meeting, Program with Abstracts, 25; on CD-ROM.
- Thomas, M.D., and Gibb, R.A., 1985. Proterozoic plate subduction and collision: processes for reactivation of Archean crust in the Churchill Province. *In Evolution of Archean supracrustal sequences. Edited by: L.D. Ayers, P.C. Thurston, K.D. Card, and W. Weber. Geological Association of Canada, Special Paper 28: 264-279.*
- Twiss, R.J., and Moores, E.M., 1992. Structural Geology. W.H. Freeman and Company, New York.
- Van Schmus, W.R., Persons, S.S., MacDonald, R., and Sibbald, T.I.L., 1986. Preliminary results from U-Pb zircon geochronology of the Uranium City region, northwest Saskatchewan. *In Summary of Investigations 1986. Saskatchewan Geology Survey Miscellaneous Report 1986-4: 108-111.*

- Wallis, R.H., 1970. The geology of the Dufferin Lake area (west half), Saskatchewan. Saskatchewan Department of Mineral Resources, Report 132.
- Wanless, R.K., 1979. Geochronology of Archean rocks of the Churchill province. Geological Association of Canada, Programs Abstract 4: 85.
- Wanless, R.K., and Eade, K.E., 1975. Geochronology of Archean and Proterozoic rocks in the southern district of Keewatin. Canadian Journal of Earth Sciences, 12: 95 - 114.
- Wheeler, J.O., Hoffman, P.F., Card, K.D., Davidson, A., Sanford, B.V., Okulitch, A.V., and Roest, W.R., 1996. Geological map of Canada/Carte geological du Canada. Geological Survey of Canada, "A" Series Map, 1860A.
- Wright, G.M., 1955. Geological notes on central District of Keewatin, Northwest Territories. Geological Survey of Canada, Paper 79 - 2.
- Wright, G.M., 1967. Geology on the southeastern barren grounds, parts of the Districts of Mackenzie and Keewatin. Geological Survey of Canada, Memoir 350.
- Yardley, B.W., 1989. An introduction to metamorphic petrology. Logman Scientific & Technical, Edinburgh Gate, England. 248 p.
- Zaleski, E., Davis, W.J., Pehrsson, S.J., Duke, N.A., L'Heureau, R., Greiner, E., 2000. Archean continental rifting recorded by orthoquartzite and bimodal komatiitic-felsic magmatism in the Woodburn Lake group, Western Churchill province, Nunavut. Geological Association of Canada Annual Meeting, Program with Abstracts, 25; on CD-ROM.

Appendix A: Modal mineral abundances for Nowyak hanging wall rocks

See maps 1 and 2 in pocket for sample locations.

Qtz - quartz	Tit - titanite
Bt - biotite	Ilm - ilmenite
Hbl - hornblende	Py - pyrite
Pl - plagioclase	Opq - opaques
Rut - rutile	Ap - apatite
Calc - calcite	Zr - zircon
Ep - Epidote	Mz - monazite

Kaminak Lake greenstone belt

Sample	Primary minerals					Accessory minerals						
	Qtz	Hbl	Act	Pl	Bt	Rut	Tit	Ilm	Py	Opq	Ap	Zr/Mz
CR96-0532	15	15	45	20	<5				x	x		
IL96-2166	10	20	55	10	5				x	x		

Yathkyed Lake greenstone belt

Sample	Primary minerals						Accessory minerals						
	Qtz	Hbl*	Act*	Pl	Bt	Calc	Rut	Tit	Ilm	Py	Opq	Ap	Zr/Mz
MT98-159	30	40	?	20	?	10	x			x	x		
MT98-155	35		30	25		15				x	x		
CS96-1302	10	70	55			20				x	x		

** MT98-159 and MT98-155 consist of very fine grained hornblende and or actinolite, and it is very difficult to positively distinguish between the two.

Appendix B: Modal mineral abundances for Nowyak shear zone rocks

See maps 1 and 2 in pocket for sample locations.

Qtz - quartz
 Bt - biotite
 Hbl - hornblende
 Pl - plagioclase
 Rut - rutile
 Calc - calcite
 Ep - Epidote
 Tit - titanite
 Ilm - ilmenite
 Py - pyrite
 Opq - opaques
 Ap - apatite
 Zr - zircon
 Mz - monazite

Sample	Primary minerals				Accessory minerals								
	Qtz	Hbl	Act	Chl	Pl	Bt	Ep	Calc	Ilm	Py	Opq	Zr/Mz	Rt
MT98-109	10	20		40	15		10	5			5		
MT98-118a	25			50	10	5	10			x	5		
MT98-118b	25			50	10	5	10				5		
MT98-127	20			40	30		10	10					
MT98-128	20		20	40	20								
MT98-129	15	5		50	15		10	5					
MT98-130a	20			40	15	10	20					x	x
MT98-130b	20			40	15	10	20					x	x
MT98-135a	15	40	10	10	15	2				10			
MT98-135b	15	40	10	10	15	2				10			
MT98-137a	10	60	20		10			2					
MT98-137b	10	75	5		10								
MT98-137c	10	60	15	10	2	5							
MT98-138	40		25	35									
MT98-154a	20	5		30	35			5			5		x
MT98-154b	20	5		30	30			10					x
MT98-157	10	5	50	25	15			5					
MT98-158	10		30		40			10		10			

Appendix C: Modal mineral abundances for Nowyak footwall rocks

See maps 1 and 2 in pocket for sample locations.

Qtz - quartz	Calc - calcite
Bt - biotite	Ep - Epidote
Hbl - hornblende	Cz - clinozoisite
Pl - plagioclase	Tit - titanite
Ms - muscovite	Ilm - ilmenite
Gt - garnet	Py - pyrite
Ky - kyanite	Opq - opaques
Chl - chlorite	Ap - apatite
K-felds - potassium feldspar	Zr - zircon
Rut - rutile	Mz - monazite

Biotite schist

Sample	Primary minerals				Accessory minerals						
	Qtz	Bt	Pl	Ms	Chl	Kfeld	Rut	Py	Opq	Ap	Zr/Mz
MT98-119	60	20	5		10		x	x	x		x

Meta-granite

Sample	Primary minerals			Accessory minerals							
	Qtz	Bt	Pl	Ms	Chl	Kfeld	Tit	Py	Opq	Ap	Zr/Mz
MT98-167a	25	13	25		2	35	x		x	x	x
IL96-2260a	20	4	24		2	45	x	x	x	x	x
IL96-2260b	20	5	20	2	3	45	x	x	x	x	x
CS96-1125	40	10	20			30		x	x	x	x

Appendix C: Modal mineral abundances for Nowyak footwall rocks (continued).

Garnet amphibolite																	
Sample	Primary minerals				Accessory minerals												
	Qtz	Hbl	Bt	Pl	Gt	Chl	Calc	Ep	Cz	Rut	Tit	Ilm	Py	Opq	Ap	Zr/Mz	
BLB97-003a	30	20	10	20	20		x		x			x	x	x		x	
BLB97-003b	20	55	3	15	5	2	x					x	x				
BLB97-003d	5	60	10	8	10	2		x						x			
BLB97-003f	20	50	10	8	10	2							x	x	x		
BLB97-003F	50	20	10	5	10		x		x	x				x			
BLB97-005a	35	10	15	30	10												
BLB97-005b	35	10	15	30	10								x	x			
BLB97-010a	20	60	5	10	5		x						x	x			
BLB97-010b	15	60	5	15	5				x	x				x			
BLB97-010c	15	55	10	10	<5				5		x			x			
BLB-1168	20	55		15	10				5	x		x		x			
BLB-3163a	10	70	5	5	10				x			x		x			
MT98-102	30	30		10	5				25	x		x		x			
MT98-145	15	70	<1	10	5							x		x			

<i>Psammite, semi-pelite, pelite schist</i>		Accessory minerals											
Sample	Primary minerals	Qtz	Bt	Pl	Ms	Gt	Ky	Rut	Ilm	Chl	Tit	Ap	Zr/Mz
MT98-165		40	30	30					x				
MT98-166		30	40	30									
MT98-101Ba		45	25	10	10	10							
MT98-101Bb		45	30	5	15	5							
MT98-146		45	20	10	5	15	5						
BLB98-003c		20	30	15	15	10	10						
BLB97-003e		25	40	10	5	15	5						
BLB97-3164		30	30	5	15	15	5						

CR96-0532 Hornblende

Sample	H12	H13	H14	H15	H16	H17	H18	H19	H32	H33	H34
SiO ₂	43.40	43.37	44.71	42.79	38.62	44.32	43.29	43.39	48.21	51.62	43.99
Al ₂ O ₃	12.13	12.21	11.09	13.52	26.77	11.86	12.28	12.52	8.41	5.14	12.16
TiO ₂	0.22	0.25	0.24	0.36	0.07	0.33	0.28	0.30	0.21	0.10	0.30
Cr ₂ O ₃	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.02	0.02
FeO	18.74	17.99	18.10	18.76	8.43	18.63	19.49	19.45	16.17	13.93	18.36
MnO	0.29	0.27	0.30	0.24	0.11	0.21	0.26	0.26	0.29	0.28	0.32
K ₂ O	0.75	0.70	0.67	0.83	0.07	0.33	0.44	0.44	0.29	0.19	0.56
MgO	8.51	9.33	9.13	7.64	0.00	8.48	8.30	7.91	11.44	13.37	8.84
CaO	12.05	11.60	11.89	11.88	23.46	11.81	11.80	11.64	11.92	11.92	11.39
Na ₂ O	1.15	1.09	1.07	1.13	0.02	1.05	1.14	1.11	0.73	0.36	1.14
CL	0.03	0.05	0.03	0.03	0.02	0.02	0.03	0.05	0.00	0.00	0.00
F	0.01	0.00	0.00	0.06	0.00	0.01	0.05	0.00	0.00	0.00	0.03
Total	97.28	96.86	97.23	97.24	97.57	97.06	97.36	97.07	97.67	96.93	97.11

Number of cations in formula based on n oxygens

n	23	23	23	23	23	23	23	23	23	23	23
Si	6.58	6.57	6.74	6.49	5.66	6.69	6.57	6.59	7.10	7.54	6.64
Al iv	1.42	1.43	1.26	1.51	2.34	1.31	1.43	1.41	0.90	0.46	1.36
Al vi	0.75	0.75	0.71	0.90	2.28	0.80	0.76	0.83	0.56	0.42	0.80
Ti	0.03	0.03	0.03	0.04	0.01	0.04	0.03	0.03	0.02	0.01	0.03
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe	2.38	2.28	2.28	2.38	1.03	2.35	2.47	2.47	1.99	1.70	2.32
Mn	0.04	0.03	0.04	0.03	0.01	0.03	0.03	0.03	0.04	0.03	0.04
K	0.15	0.14	0.13	0.16	0.01	0.06	0.09	0.09	0.05	0.04	0.11
Mg	1.92	2.11	2.05	1.73	0.00	1.91	1.88	1.79	2.51	2.91	1.99
Ca	1.96	1.88	1.92	1.93	3.68	1.91	1.92	1.89	1.88	1.86	1.84
Na	0.34	0.32	0.31	0.33	0.01	0.31	0.34	0.33	0.21	0.10	0.33
Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F	0.00	0.00	0.00	0.03	0.00	0.00	0.02	0.00	0.00	0.00	0.01
Fe/Fe+Mg	0.55	0.52	0.53	0.58	1.00	0.55	0.57	0.58	0.44	0.37	0.54

CR96-0532 Hornblende (continued)

Sample	H35	H36	H37	H38	H39	H40	H40b	H41	H44	H45	H46
SiO ₂	42.24	43.47	44.76	44.33	44.78	44.97	43.17	43.78	44.51	45.39	43.14
Al ₂ O ₃	13.64	12.71	10.95	11.29	11.33	11.21	13.08	11.92	11.45	10.74	11.80
TiO ₂	0.35	0.29	0.25	0.27	0.27	0.26	0.35	0.34	0.25	0.26	0.31
Cr ₂ O ₃	0.00	0.03	0.00	0.00	0.02	0.04	0.02	0.01	0.05	0.00	0.05
FeO	19.72	19.14	18.40	17.93	18.11	18.00	19.40	18.36	18.34	18.13	18.84
MnO	0.24	0.32	0.21	0.28	0.27	0.32	0.26	0.26	0.27	0.25	0.26
K ₂ O	0.39	0.39	0.25	0.29	0.25	0.27	0.39	0.33	0.36	0.34	0.39
MgO	7.53	8.10	9.31	8.71	9.10	9.26	8.05	8.51	9.09	9.16	8.44
CaO	11.88	11.97	11.70	11.91	11.97	11.65	11.68	11.58	11.72	11.86	11.72
Na ₂ O	1.13	1.17	1.02	1.02	0.97	1.04	1.26	1.06	1.04	1.03	1.17
CL	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.01	0.04	0.01
F	0.01	0.00	0.00	0.09	0.00	0.02	0.00	0.03	0.04	0.06	0.02
Total	97.13	97.59	96.85	96.12	97.07	97.04	97.68	96.18	97.13	97.26	96.15

Number of cations in formula based on n oxygens

n	23	23	23	23	23	23	23	23	23	23	23
Si	6.43	6.56	6.76	6.74	6.74	6.76	6.51	6.67	6.71	6.82	6.61
Al iv	1.57	1.44	1.24	1.26	1.26	1.24	1.49	1.33	1.29	1.18	1.39
Al vi	0.88	0.82	0.70	0.77	0.75	0.75	0.84	0.80	0.74	0.72	0.74
Ti	0.04	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.03	0.03	0.04
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01
Fe	2.51	2.41	2.32	2.28	2.28	2.26	2.45	2.34	2.31	2.28	2.41
Mn	0.03	0.04	0.03	0.04	0.03	0.04	0.03	0.03	0.03	0.03	0.03
K	0.08	0.08	0.05	0.06	0.05	0.05	0.08	0.06	0.07	0.07	0.08
Mg	1.71	1.82	2.09	1.98	2.04	2.08	1.81	1.93	2.04	2.05	1.93
Ca	1.94	1.93	1.89	1.94	1.93	1.88	1.89	1.89	1.89	1.91	1.92
Na	0.33	0.34	0.30	0.30	0.28	0.30	0.37	0.31	0.30	0.30	0.35
Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F	0.00	0.00	0.00	0.04	0.00	0.01	0.00	0.01	0.02	0.03	0.01
Fe/Fe+Mg	0.59	0.57	0.53	0.54	0.53	0.52	0.57	0.55	0.53	0.53	0.56

CR96-0532 Hornblende (continued)

Sample	H47	H48	H49	H50	H51
SiO ₂	42.92	48.84	43.42	42.97	42.74
Al ₂ O ₃	11.85	9.52	11.73	12.46	12.92
TiO ₂	0.23	0.21	0.28	0.32	0.29
Cr ₂ O ₃	0.00	0.01	0.00	0.00	0.00
FeO	18.93	17.27	18.38	19.16	19.36
MnO	0.31	0.29	0.32	0.37	0.36
K ₂ O	0.32	0.31	0.40	0.41	0.42
MgO	8.11	8.88	8.93	8.18	7.99
CaO	11.67	10.89	11.87	11.78	11.64
Na ₂ O	1.15	0.91	1.03	1.19	1.25
Cl	0.03	0.03	0.01	0.01	0.05
F	0.00	0.06	0.05	0.04	0.05
Total	95.52	97.22	96.42	96.89	97.07

Number of cations in formula based on n oxygens

n	23	23	23	23	23
Si	6.62	7.22	6.62	6.54	6.50
Al iv	1.38	0.78	1.38	1.46	1.50
Al vi	0.77	0.88	0.72	0.78	0.82
Ti	0.03	0.02	0.03	0.04	0.03
Cr	0.00	0.00	0.00	0.00	0.00
Fe	2.44	2.14	2.34	2.44	2.46
Mn	0.04	0.04	0.04	0.05	0.05
K	0.06	0.06	0.08	0.08	0.08
Mg	1.86	1.96	2.03	1.86	1.81
Ca	1.93	1.73	1.94	1.92	1.90
Na	0.34	0.26	0.30	0.35	0.37
Cl	0.00	0.00	0.00	0.00	0.00
F	0.00	0.03	0.02	0.02	0.02
Fe/Fe+Mg	0.57	0.52	0.54	0.57	0.58

CR96-0532 Plagioclase

Sample	P4	P5	P6	P8	P9	P10	P11	P20	P21	P22	P23
SiO ₂	62.92	61.76	62.81	63.60	62.54	61.92	62.59	63.03	62.58	61.37	61.67
Al ₂ O ₃	24.52	24.96	24.58	23.47	24.53	25.15	24.16	23.97	24.75	24.85	24.83
K ₂ O	0.16	0.29	0.16	0.27	0.19	0.16	0.95	0.27	0.13	0.97	0.26
CaO	5.42	5.93	5.46	4.62	5.61	5.90	5.17	4.96	5.71	5.26	5.89
Na ₂ O	8.56	8.36	8.58	8.75	8.58	8.53	8.43	8.46	8.33	7.63	7.85
FeO	0.14	0.08	0.13	0.22	0.12	0.19	0.10	0.29	0.09	0.28	0.28
Total	101.72	101.38	101.72	100.93	101.57	101.85	101.40	100.98	101.59	100.36	100.78

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.74	2.71	2.74	2.79	2.73	2.70	2.75	2.77	2.73	2.72	2.72
Al	1.26	1.29	1.26	1.21	1.26	1.29	1.25	1.24	1.27	1.30	1.29
K	0.01	0.02	0.01	0.02	0.01	0.01	0.05	0.02	0.01	0.05	0.01
Ca	0.25	0.28	0.26	0.22	0.26	0.28	0.24	0.23	0.27	0.25	0.28
Na	0.72	0.71	0.73	0.74	0.73	0.72	0.72	0.72	0.70	0.66	0.67
Fe	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.01
% Ab	73.4	70.7	73.3	76.2	72.7	71.7	70.8	74.4	72.0	68.3	69.6
% An	25.7	27.7	25.8	22.2	26.3	27.4	24.0	24.1	27.3	26.0	28.9
% Or	0.9	1.6	0.9	1.5	1.1	0.9	5.2	1.6	0.7	5.7	1.5

CR96-0532 Plagioclase (Continued)

Sample	P24	P25	P26	P27	P28	P29	P30	P31	P43	P44	P45
SiO ₂	61.79	62.96	62.84	62.02	62.76	62.06	61.74	62.43	61.59	61.50	62.30
Al ₂ O ₃	24.95	23.67	23.76	24.48	24.03	24.42	24.56	24.61	24.33	24.31	23.96
K ₂ O	0.21	0.47	0.09	0.08	0.07	0.08	0.08	0.08	0.06	0.08	0.06
CaO	5.99	4.81	5.14	5.81	5.45	5.97	5.78	5.83	5.97	6.06	5.53
Na ₂ O	7.98	8.50	8.45	8.21	8.30	7.94	8.36	8.16	7.76	8.30	8.34
FeO	0.14	0.22	0.19	0.20	0.17	0.15	0.24	0.17	0.33	0.36	0.15
Total	101.06	100.63	100.47	100.80	100.78	100.62	100.76	101.28	100.04	100.61	100.34

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.71	2.77	2.77	2.73	2.76	2.73	2.72	2.73	2.73	2.72	2.75
Al	1.29	1.23	1.23	1.27	1.24	1.27	1.28	1.27	1.27	1.27	1.25
K	0.01	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ca	0.28	0.23	0.24	0.27	0.26	0.28	0.27	0.27	0.28	0.29	0.26
Na	0.68	0.73	0.72	0.70	0.71	0.68	0.71	0.69	0.67	0.71	0.71
Fe	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
%Ab	69.8	74.1	74.5	71.6	73.1	70.3	72.0	71.4	69.9	70.9	72.9
%An	29.0	23.2	25.0	28.0	26.5	29.2	27.5	28.2	29.7	28.6	26.7
%Or	1.2	2.7	0.5	0.5	0.4	0.5	0.5	0.5	0.4	0.4	0.3

CR96-0532 Plagioclase (continued)

Sample	P46	P52	P53	P54	P55	P56	P57	P58	P59	P60	P61
SiO ₂	62.68	62.41	61.63	62.50	62.29	63.25	62.44	62.43	62.52	62.13	62.99
Al ₂ O ₃	23.60	24.57	24.01	23.87	24.51	23.93	24.64	23.76	24.10	24.62	24.48
K ₂ O	0.05	0.03	0.76	0.07	0.15	0.11	0.07	0.07	0.73	0.08	0.07
CaO	5.40	5.76	5.23	5.42	5.74	4.97	5.87	5.33	5.10	5.84	5.46
Na ₂ O	8.60	8.44	7.86	8.68	8.45	9.04	8.41	8.67	8.35	8.40	8.58
FeO	0.21	0.03	0.08	0.22	0.21	0.34	0.23	0.18	0.10	0.35	0.31
Total	100.54	101.24	99.57	100.76	101.35	101.64	101.66	100.44	100.90	101.42	101.89

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.76	2.73	2.75	2.75	2.73	2.76	2.73	2.76	2.75	2.72	2.74
Al	1.23	1.27	1.26	1.24	1.27	1.23	1.27	1.24	1.25	1.27	1.26
K	0.00	0.00	0.04	0.00	0.01	0.01	0.00	0.00	0.04	0.00	0.00
Ca	0.26	0.27	0.25	0.26	0.27	0.23	0.27	0.25	0.24	0.27	0.25
Na	0.74	0.72	0.68	0.74	0.72	0.77	0.71	0.74	0.71	0.71	0.72
Fe	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01
%Ab	74.0	72.5	69.9	74.1	72.1	76.2	71.9	74.3	71.7	71.9	73.7
%An	25.7	27.3	25.7	25.6	27.1	23.2	27.7	25.3	24.2	27.6	25.9
%Or	0.3	0.2	4.4	0.4	0.8	0.6	0.4	0.4	4.1	0.5	0.4

IL96-2166 Hornblende

Sample	H17	H18	H19	H10	H11	H12	H13	H14	H21	H22	H23
SiO ₂	41.75	41.67	41.07	41.04	40.55	40.47	42.12	41.78	40.88	40.87	41.36
Al ₂ O ₃	14.58	14.96	14.28	14.07	14.79	14.25	15.03	14.49	16.07	15.97	15.57
TiO ₂	0.28	0.31	0.16	0.11	0.32	0.33	0.31	0.30	0.20	0.29	0.35
Cr ₂ O ₃	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.03
FeO	21.02	21.09	21.66	21.53	20.56	20.45	20.30	20.76	21.01	21.10	21.10
MnO	0.30	0.34	0.27	0.25	0.28	0.23	0.28	0.23	0.24	0.32	0.36
K ₂ O	0.46	0.43	0.56	0.58	0.52	0.47	0.51	0.47	0.51	0.50	0.49
MgO	6.09	6.00	6.13	6.02	5.86	6.08	5.85	6.11	5.29	5.40	5.53
CaO	11.84	11.61	11.84	11.92	11.74	11.77	11.64	11.87	11.81	11.72	11.72
Na ₂ O	1.19	1.13	1.13	1.08	1.40	1.18	1.51	1.14	1.18	1.16	1.26
CL	0.02	0.01	0.01	0.02	0.02	0.01	0.01	0.00	0.03	0.02	0.00
F	0.06	0.00	0.00	0.03	0.00	0.03	0.02	0.00	0.02	0.08	0.04
Total	97.59	97.55	97.11	96.65	96.04	95.27	97.58	97.15	97.26	97.43	97.81

Number of cations in formula based on n oxygens

n	23	23	23	23	23	23	23	23	23	23	23
Si	6.37	6.35	6.33	6.36	6.29	6.33	6.40	6.39	6.26	6.25	6.30
Al iv	1.63	1.65	1.67	1.64	1.71	1.67	1.60	1.61	1.74	1.75	1.70
Al vi	0.99	1.04	0.92	0.92	1.00	0.96	1.09	1.00	1.15	1.13	1.09
Ti	0.03	0.04	0.02	0.01	0.04	0.04	0.04	0.03	0.02	0.03	0.04
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe	2.68	2.69	2.79	2.79	2.67	2.67	2.58	2.65	2.69	2.70	2.69
Mn	0.04	0.04	0.04	0.03	0.04	0.03	0.04	0.03	0.03	0.04	0.05
K	0.09	0.08	0.11	0.11	0.10	0.09	0.10	0.09	0.10	0.10	0.10
Mg	1.39	1.36	1.41	1.39	1.36	1.42	1.32	1.39	1.21	1.23	1.26
Ca	1.94	1.90	1.95	1.98	1.95	1.97	1.89	1.94	1.94	1.92	1.91
Na	0.35	0.33	0.34	0.32	0.42	0.36	0.44	0.34	0.35	0.34	0.37
Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F	0.03	0.00	0.00	0.01	0.00	0.01	0.01	0.00	0.01	0.04	0.02
Fe/Fe+Mg	0.66	0.66	0.66	0.67	0.66	0.65	0.66	0.66	0.69	0.69	0.68

IL-96-2166 Hornblende (Continued)

Sample	H24	H29	H30
SiO ₂	41.10	41.88	41.74
Al ₂ O ₃	15.52	14.65	14.80
TiO ₂	0.32	0.29	0.31
Cr ₂ O ₃	0.03	0.00	0.00
FeO	21.55	20.42	20.81
MnO	0.28	0.19	0.31
K ₂ O	0.48	0.43	0.44
MgO	5.99	6.03	6.21
CaO	11.74	11.65	11.64
Na ₂ O	1.21	1.30	1.16
CL	0.02	0.00	0.01
F	0.00	0.09	0.09
Total	98.24	96.93	97.52

Number of cations in formula based on n oxygens

n	23	23	23
Si	6.24	6.41	6.36
Al ^{iv}	1.76	1.59	1.64
Al ^{vi}	1.02	1.05	1.02
Ti	0.04	0.03	0.04
Cr	0.00	0.00	0.00
Fe	2.74	2.61	2.65
Mn	0.04	0.02	0.04
K	0.09	0.08	0.09
Mg	1.36	1.38	1.41
Ca	1.91	1.91	1.90
Na	0.36	0.39	0.34
Cl	0.00	0.00	0.00
F	0.00	0.04	0.04
Fe/Fe+Mg	0.67	0.66	0.65

IL96-2166 Plagioclase

Sample	P1	P2	P3	P4	P5	P6	P15	P16	P17	P18	P19
SiO ₂	60.88	60.98	61.85	62.31	61.50	61.25	61.77	61.24	61.97	63.24	61.83
Al ₂ O ₃	25.56	25.96	25.44	25.18	25.39	25.70	25.69	25.62	25.15	24.07	25.28
K ₂ O	0.10	0.09	0.05	0.08	0.25	0.06	0.07	0.05	0.07	0.08	0.30
CaO	6.23	6.37	5.93	5.53	6.24	6.40	6.25	6.45	5.90	5.01	6.12
Na ₂ O	8.24	8.31	8.48	8.78	8.09	8.24	8.10	8.02	8.37	9.04	8.01
FeO	0.36	0.16	0.12	0.10	0.54	0.22	0.07	0.11	0.03	0.06	0.14
Total	101.37	101.87	101.87	101.98	102.01	101.87	101.95	101.49	101.49	101.50	101.68

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.68	2.67	2.70	2.71	2.69	2.68	2.69	2.68	2.71	2.76	2.70
Al	1.32	1.34	1.31	1.29	1.31	1.32	1.32	1.32	1.30	1.24	1.30
K	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.02
Ca	0.29	0.30	0.28	0.26	0.29	0.30	0.29	0.30	0.28	0.23	0.29
Na	0.70	0.70	0.72	0.74	0.69	0.70	0.68	0.68	0.71	0.77	0.68
Fe	0.01	0.01	0.00	0.00	0.02	0.01	0.01	0.00	0.00	0.00	0.01
% Ab	70.1	69.9	71.9	73.9	69.1	69.7	69.8	69.0	71.7	76.2	69.1
% An	29.3	29.6	27.8	25.7	29.5	29.9	29.8	30.7	27.9	23.3	29.2
% Or	0.6	0.5	0.3	0.4	1.4	0.3	0.4	0.3	0.4	0.4	1.7

IL96-2166 Plagioclase (Continued)

Sample	P20	P25	P26	P27	P28
SiO ₂	63.13	61.58	62.81	61.72	61.64
Al ₂ O ₃	23.87	25.39	25.01	25.51	25.45
K ₂ O	1.00	0.28	1.30	0.09	0.08
CaO	4.99	6.28	5.40	6.38	6.40
Na ₂ O	8.09	7.92	7.88	8.09	8.01
FeO	0.85	0.40	0.43	0.29	0.31
Total	101.93	101.85	102.83	102.08	101.89

Number of cations in formula based on n oxygens

n	8	8	8	8	8
Si	2.76	2.69	2.72	2.69	2.69
Al	1.23	1.31	1.28	1.31	1.31
K	0.06	0.02	0.07	0.01	0.00
Ca	0.23	0.29	0.25	0.30	0.30
Na	0.69	0.67	0.66	0.68	0.68
Fe	0.03	0.01	0.02	0.01	0.01
%Ab	70.3	68.4	67.2	69.3	69.1
%An	24.0	30.0	25.5	30.2	30.5
%Or	5.7	1.6	7.3	0.5	0.5

YD98-3044 Hornblende

Sample	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11
SiO ₂	45.38	43.26	44.44	44.32	43.40	44.32	44.33	43.24	43.36	42.93	43.46
Al ₂ O ₃	10.75	12.51	11.35	11.98	13.12	12.35	11.99	13.45	12.73	12.83	12.93
TiO ₂	0.28	0.42	0.31	0.38	0.32	0.36	0.32	0.36	0.35	0.30	0.28
Cr ₂ O ₃	0.04	0.05	0.00	0.00	0.00	0.01	0.00	0.00	0.05	0.00	0.03
FeO	13.51	15.16	14.19	14.25	14.96	14.28	14.65	15.26	15.18	15.37	15.38
MnO	0.24	0.31	0.20	0.21	0.26	0.22	0.29	0.29	0.30	0.39	0.28
K ₂ O	0.26	0.31	0.31	0.37	0.29	0.34	0.24	0.30	0.37	0.39	0.36
MgO	12.39	11.04	12.37	11.56	10.99	11.61	11.74	10.92	10.96	10.99	10.91
CaO	12.29	12.24	12.12	12.23	12.14	12.16	12.08	11.95	11.99	12.24	11.93
Na ₂ O	1.26	1.44	1.24	1.38	1.52	1.35	1.44	1.46	1.30	1.30	1.43
CL	0.00	0.02	0.00	0.01	0.02	0.00	0.01	0.00	0.01	0.00	0.01
F	0.24	0.26	0.25	0.26	0.35	0.26	0.30	0.31	0.24	0.32	0.32
Total	96.04	97.02	96.78	96.95	97.37	97.26	97.39	97.54	96.84	97.06	97.32

Number of cations in formula based on n oxygens

n	23	23	23	23	23	23	23	23	23	23	23
Si	6.74	6.48	6.63	6.60	6.47	6.58	6.59	6.44	6.50	6.45	6.49
Al iv	1.26	1.52	1.37	1.40	1.53	1.42	1.41	1.56	1.50	1.55	1.51
Al vi	0.63	0.69	0.62	0.71	0.78	0.74	0.68	0.80	0.75	0.72	0.77
Ti	0.03	0.05	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03
Cr	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Fe	1.68	1.90	1.77	1.78	1.87	1.77	1.82	1.90	1.90	1.93	1.92
Mn	0.03	0.04	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.05	0.04
K	0.05	0.06	0.06	0.07	0.06	0.06	0.05	0.06	0.07	0.07	0.07
Mg	2.75	2.47	2.75	2.57	2.44	2.57	2.60	2.42	2.45	2.46	2.43
Ca	1.96	1.97	1.94	1.95	1.94	1.93	1.92	1.91	1.93	1.97	1.91
Na	0.36	0.42	0.36	0.40	0.44	0.39	0.41	0.42	0.38	0.38	0.41
Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F	0.11	0.12	0.12	0.12	0.17	0.12	0.14	0.15	0.11	0.15	0.15
Fe/Fe+Mg	0.38	0.44	0.39	0.41	0.43	0.41	0.41	0.44	0.44	0.44	0.44

YD98-3044 Hornblende (Continued)

Sample	H12	H13	H14	H15	H16	H17	H18	H19	H20
SiO ₂	42.92	43.63	43.69	43.72	44.94	44.93	43.53	44.47	46.18
Al ₂ O ₃	13.37	12.62	12.55	12.31	11.46	10.89	12.73	11.49	10.27
TiO ₂	0.28	0.34	0.36	0.37	0.41	0.40	0.37	0.30	0.29
Cr ₂ O ₃	0.06	0.17	0.00	0.00	0.02	0.06	0.02	0.06	0.00
FeO	15.35	14.97	14.98	14.78	14.42	14.18	15.17	14.62	13.57
MnO	0.24	0.27	0.31	0.26	0.25	0.25	0.30	0.24	0.22
K ₂ O	0.29	0.37	0.35	0.43	0.39	0.25	0.37	0.28	0.21
MgO	10.77	11.39	11.29	11.73	11.81	12.15	10.79	11.57	12.57
CaO	12.17	11.95	12.16	11.91	12.11	12.14	11.89	12.25	11.98
Na ₂ O	1.51	1.44	1.36	1.30	1.17	1.19	1.42	1.31	1.08
CL	0.00	0.00	0.01	0.02	0.01	0.01	0.03	0.00	0.00
F	0.32	0.29	0.32	0.32	0.28	0.31	0.26	0.27	0.29
Total	97.28	97.44	97.38	97.15	97.27	96.76	96.88	96.86	96.66

Number of cations in formula based on n oxygens

n	23	23	23	23	23	23	23	23	23
Si	6.42	6.50	6.51	6.52	6.67	6.70	6.52	6.64	6.84
Al iv	1.58	1.50	1.49	1.48	1.33	1.30	1.48	1.36	1.16
Al vi	0.78	0.71	0.72	0.69	0.67	0.61	0.77	0.66	0.64
Ti	0.03	0.04	0.04	0.04	0.05	0.04	0.04	0.03	0.03
Cr	0.01	0.02	0.00	0.00	0.00	0.01	0.00	0.01	0.00
Fe	1.92	1.86	1.87	1.84	1.79	1.77	1.90	1.83	1.68
Mn	0.03	0.03	0.04	0.03	0.03	0.03	0.04	0.03	0.03
K	0.06	0.07	0.07	0.08	0.07	0.05	0.07	0.05	0.04
Mg	2.40	2.53	2.51	2.61	2.61	2.70	2.41	2.58	2.78
Ca	1.95	1.91	1.94	1.90	1.92	1.94	1.91	1.96	1.90
Na	0.44	0.42	0.39	0.38	0.34	0.34	0.41	0.38	0.31
Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F	0.15	0.14	0.15	0.15	0.13	0.15	0.12	0.13	0.14
Fe/Fe+Mg	0.44	0.42	0.43	0.41	0.41	0.40	0.44	0.41	0.38

YD98-3044 Plagioclase

Sample	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30	P31
SiO ₂	47.68	48.78	46.80	46.70	47.05	47.61	49.09	47.46	49.67	49.19	50.38
Al ₂ O ₃	33.29	32.55	34.52	34.35	33.64	32.94	33.22	33.71	32.15	32.28	32.02
K ₂ O	0.01	0.01	0.00	0.00	0.00	0.04	0.01	0.00	0.02	0.01	0.01
CaO	16.46	15.90	17.67	17.89	17.38	16.36	15.90	16.78	15.16	15.29	14.84
Na ₂ O	1.90	2.70	1.49	1.47	1.69	2.34	2.50	2.06	3.02	3.05	3.16
FeO	0.20	0.14	0.12	0.07	0.10	0.03	0.30	0.33	0.13	0.07	0.17
Total	99.54	100.08	100.60	100.48	99.86	99.32	101.02	100.34	100.15	99.89	100.58

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.19	2.23	2.14	2.14	2.16	2.20	2.22	2.17	2.26	2.25	2.28
Al	1.81	1.76	1.86	1.85	1.82	1.79	1.77	1.82	1.73	1.74	1.71
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ca	0.81	0.78	0.87	0.88	0.86	0.81	0.77	0.82	0.74	0.75	0.72
Na	0.17	0.24	0.13	0.13	0.15	0.21	0.22	0.18	0.27	0.27	0.28
Fe	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.01
%Ab	17.3	23.4	13.2	12.9	15.0	20.5	22.1	18.2	26.4	26.5	27.8
%An	82.6	76.5	86.7	87.0	85.0	79.3	77.8	81.8	73.4	73.4	72.1
%Or	0.1	0.1	0.1	0.0	0.0	0.2	0.1	0.0	0.1	0.0	0.1

YD98-3044 Plagioclase (Continued)

Sample	P32	P33	P34	P35	P36	P37	P38	P39	P40
SiO ₂	47.28	49.20	48.54	49.82	47.92	48.41	47.42	48.13	47.28
Al ₂ O ₃	34.00	32.20	33.15	32.58	33.81	33.53	34.00	33.06	34.08
K ₂ O	0.01	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.02
CaO	16.87	15.30	16.63	15.13	16.98	16.58	17.25	16.33	17.44
Na ₂ O	1.96	2.77	2.30	3.13	2.01	2.13	1.89	2.24	1.85
FeO	0.18	0.23	0.22	0.38	0.11	0.20	0.08	0.26	0.12
Total	100.30	99.72	100.85	101.06	100.84	100.86	100.65	100.03	100.79

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8
Si	2.16	2.25	2.21	2.25	2.18	2.20	2.16	2.21	2.16
Al	1.83	1.74	1.78	1.74	1.81	1.80	1.83	1.79	1.83
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ca	0.83	0.75	0.81	0.73	0.83	0.81	0.84	0.80	0.85
Na	0.17	0.25	0.20	0.28	0.18	0.19	0.17	0.20	0.16
Fe	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.01	0.00
% Ab	17.3	24.6	20.0	27.2	17.7	18.8	16.6	19.8	16.1
% An	82.6	75.3	79.9	72.6	82.3	81.1	83.4	80.1	83.8
% Or	0.0	0.1	0.1	0.1	0.0	0.1	0.0	0.0	0.1

MT98-129 Plagioclase

Sample	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19
SiO ₂	61.65	62.11	60.14	60.79	62.34	61.91	62.56	62.33	62.27	61.48	62.45
Al ₂ O ₃	25.23	25.03	24.54	25.74	24.58	24.87	24.55	24.09	24.75	25.09	25.16
K ₂ O	0.04	0.07	0.06	0.05	0.03	0.03	0.03	0.02	0.03	0.04	0.03
CaO	5.78	5.81	6.36	6.61	5.57	5.51	5.05	5.22	5.39	5.55	5.73
Na ₂ O	8.56	8.38	7.85	7.47	8.59	7.86	8.22	7.58	7.91	8.59	7.82
FeO	0.35	0.35	1.15	0.44	0.53	0.58	0.54	0.51	0.43	0.43	0.46
Total	101.61	101.75	100.1	101.1	101.64	100.76	100.95	99.75	100.78	101.18	101.65

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.70	2.71	2.69	2.67	2.73	2.72	2.74	2.76	2.74	2.70	2.72
Al	1.30	1.29	1.29	1.33	1.27	1.29	1.27	1.26	1.28	1.30	1.29
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ca	0.27	0.27	0.30	0.31	0.26	0.26	0.24	0.25	0.25	0.26	0.27
Na	0.73	0.71	0.68	0.64	0.73	0.67	0.70	0.65	0.67	0.73	0.66
Fe	0.01	0.01	0.04	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
% Ab	72.7	72.0	68.8	67.0	73.5	71.9	74.5	72.3	72.5	73.5	71.1
% An	27.1	27.6	30.8	32.7	26.3	27.9	25.3	27.5	27.3	26.3	28.8
% Or	0.2	0.4	0.3	0.3	0.2	0.2	0.2	0.1	0.2	0.2	0.2

MT98-129 Plagioclase (Continued)

Sample	P20	P21	P22	P23	P24	P35	P36	P37	P38	P39	P40
SiO ₂	60.66	63.02	60.55	60.87	60.63	63.63	64.28	61.75	62.57	61.91	60.06
Al ₂ O ₃	25.25	23.76	25.17	25.37	25.6	23.36	23.42	24.63	24.36	24.72	25.58
K ₂ O	0.05	0.03	0.05	0.03	0.05	0.03	0.04	0.04	0.04	0.05	0.05
CaO	6.11	4.29	6.1	6.09	6.4	4	3.97	5.87	5.47	5.86	6.96
Na ₂ O	7.69	8.63	8.18	7.98	7.93	9.94	9.56	8.11	8.44	8.33	7.6
FeO	0.2	0.2	0.42	0.64	0.52	0.25	0.35	0.34	0.36	0.22	0.26
Total	99.96	99.93	100.47	100.98	101.13	101.21	101.62	100.74	101.24	101.09	100.51

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.69	2.78	2.68	2.68	2.67	2.79	2.80	2.72	2.74	2.72	2.66
Al	1.32	1.24	1.32	1.32	1.33	1.21	1.20	1.28	1.26	1.28	1.34
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ca	0.29	0.20	0.29	0.29	0.30	0.19	0.19	0.28	0.26	0.28	0.33
Na	0.66	0.74	0.70	0.68	0.68	0.84	0.81	0.69	0.72	0.71	0.65
Fe	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
% Ab	69.3	78.3	70.6	70.2	69.0	81.7	81.2	71.3	73.5	71.8	66.2
% An	30.4	21.5	29.1	29.6	30.8	18.2	18.6	28.5	26.3	27.9	33.5
% Or	0.3	0.2	0.3	0.2	0.3	0.2	0.2	0.2	0.2	0.3	0.3

MT98-129 Hornblende

Sample	H1	H2	H3	H3	H5	H6	H7	H8	H25	H26	H27
SiO ₂	42.75	42.74	42.98	42.61	42.44	42.57	42.76	42.03	41.82	41.90	41.59
Al ₂ O ₃	13.90	14.38	14.40	14.21	14.73	14.48	14.81	14.57	14.97	14.53	16.12
TiO ₂	0.34	0.20	0.30	0.32	0.40	0.41	0.23	0.34	0.35	0.36	0.08
Cr ₂ O ₃	0.05	0.03	0.06	0.04	0.08	0.04	0.08	0.07	0.16	0.10	0.03
FeO	17.86	17.83	18.46	18.39	18.47	17.90	17.61	17.98	17.69	18.94	19.17
MnO	0.30	0.28	0.24	0.26	0.27	0.23	0.26	0.30	0.26	0.32	0.16
K ₂ O	0.19	0.16	0.23	0.19	0.21	0.21	0.19	0.25	0.21	0.17	0.23
MgO	8.71	8.51	8.54	8.56	8.23	8.31	8.62	8.20	8.13	8.12	7.60
CaO	11.89	11.73	11.67	11.62	11.81	11.76	11.69	11.87	12.11	11.72	11.90
Na ₂ O	1.20	1.38	1.29	1.33	1.29	1.24	1.33	1.31	1.18	1.34	1.27
CL	0.03	0.03	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.00
F	0.04	0.01	0.05	0.02	0.03	0.05	0.03	0.03	0.10	0.06	0.05
Total	97.26	97.28	98.22	97.56	97.97	97.21	97.62	96.96	96.98	97.57	98.20

d on n oxygens

n	23	23	23	23	23	23	23	23	23	23	23
Si	6.43	6.42	6.41	6.40	6.35	6.40	6.39	6.36	6.32	6.33	6.23
Al iv	1.57	1.58	1.59	1.60	1.65	1.60	1.61	1.64	1.68	1.67	1.77
Al vi	0.90	0.97	0.94	0.92	0.95	0.97	1.00	0.95	0.99	0.91	1.08
Ti	0.04	0.02	0.03	0.04	0.05	0.05	0.03	0.04	0.04	0.04	0.01
Cr	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.01	0.02	0.01	0.00
Fe	2.25	2.24	2.30	2.31	2.31	2.25	2.20	2.27	2.24	2.39	2.40
Mn	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.04	0.03	0.04	0.02
K	0.04	0.03	0.04	0.04	0.04	0.04	0.04	0.05	0.04	0.03	0.04
Mg	1.95	1.91	1.90	1.92	1.84	1.86	1.92	1.85	1.83	1.83	1.70
Ca	1.92	1.89	1.86	1.87	1.89	1.90	1.87	1.92	1.96	1.90	1.91
Na	0.35	0.40	0.37	0.39	0.37	0.36	0.39	0.38	0.35	0.39	0.37
Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F	0.02	0.00	0.02	0.01	0.01	0.02	0.01	0.01	0.05	0.03	0.02
Fe/Fe+Mg	0.53	0.54	0.55	0.55	0.56	0.55	0.53	0.55	0.55	0.57	0.59

MT98-129 Hornblende (Continued)

Sample	H28	H29	H30	H31	H32	H33	H34
SiO ₂	43.03	42.60	41.96	42.70	42.72	44.63	43.14
Al ₂ O ₃	14.12	14.34	13.74	14.53	14.19	13.97	13.55
TiO ₂	0.28	0.32	0.10	0.36	0.38	0.27	0.34
Cr ₂ O ₃	0.06	0.04	0.07	0.08	0.07	0.02	0.06
FeO	17.37	17.62	19.24	17.70	17.68	16.89	18.03
MnO	0.22	0.28	0.20	0.25	0.19	0.13	0.32
K ₂ O	0.18	0.19	0.36	0.22	0.23	0.37	0.22
MgO	8.65	8.87	8.13	8.73	8.87	8.21	8.97
CaO	11.90	11.61	12.00	11.85	11.72	11.27	11.76
Na ₂ O	1.31	1.39	1.25	1.38	1.35	1.62	1.26
CL	0.00	0.00	0.00	0.00	0.01	0.00	0.00
F	0.03	0.07	0.00	0.05	0.03	0.06	0.10
Total	97.15	97.33	97.05	97.85	97.44	97.44	97.75

Number of cations in formula based on n oxygens

n	23	23	23	23	23	23	23
Si	6.46	6.40	6.39	6.38	6.41	6.63	6.46
Al iv	1.54	1.60	1.61	1.62	1.59	1.37	1.54
Al vi	0.96	0.93	0.85	0.94	0.91	1.08	0.86
Ti	0.03	0.04	0.01	0.04	0.04	0.03	0.04
Cr	0.01	0.00	0.01	0.01	0.01	0.00	0.01
Fe	2.18	2.21	2.45	2.21	2.22	2.10	2.26
Mn	0.03	0.04	0.03	0.03	0.02	0.02	0.04
K	0.03	0.04	0.07	0.04	0.04	0.07	0.04
Mg	1.94	1.99	1.84	1.94	1.98	1.82	2.00
Ca	1.91	1.87	1.96	1.90	1.88	1.79	1.89
Na	0.38	0.40	0.37	0.40	0.39	0.47	0.37
Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F	0.01	0.03	0.00	0.02	0.01	0.03	0.05
Fe/Fe+Mg	0.53	0.53	0.57	0.53	0.53	0.54	0.53

MT98-135 Plagioclase

Sample	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P25
SiO ₂	58.4	62.44	57.93	62.78	60.21	61.03	62.48	58.08	61.38	59.85	63.04
Al ₂ O ₃	26.48	23.85	26.72	23.5	25.74	24.4	23.74	26.24	24.47	25.62	23.45
K ₂ O	0.04	0.07	0.06	0.09	0.05	0.06	0.07	0.04	0.05	0.09	0.08
CaO	8.1	5.13	8.17	4.86	7.21	5.81	4.85	7.96	5.86	7.06	4.9
Na ₂ O	6.68	8.66	6.79	8.74	7.2	8.09	8.7	7	8.05	7.25	8.48
FeO	0.25	0.12	0.13	0.27	0.32	0.26	0.39	0.26	0.35	0.1	0.53
Total	99.95	100.27	99.8	100.24	100.73	99.65	100.23	99.58	100.16	99.97	100.48

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.61	2.76	2.60	2.77	2.66	2.72	2.76	2.61	2.72	2.66	2.78
Al	1.39	1.24	1.41	1.22	1.34	1.28	1.24	1.39	1.28	1.34	1.22
K	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Ca	0.39	0.24	0.39	0.23	0.34	0.28	0.23	0.38	0.28	0.34	0.23
Na	0.58	0.74	0.59	0.75	0.62	0.70	0.75	0.61	0.69	0.63	0.72
Fe	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.02
% Ab	59.7	75.0	59.9	76.1	64.2	71.3	76.1	61.3	71.1	64.7	75.4
% An	40.0	24.6	39.8	23.4	35.5	28.3	23.5	38.5	28.6	34.8	24.1
% Or	0.2	0.4	0.3	0.5	0.3	0.3	0.4	0.2	0.3	0.5	0.5

MT98-135 Plagioclase (Continued)

Sample	P26	P27	P28	P29	P30	P31	P32	P33	P34	P35	P36
SiO ₂	63.58	63.58	63.13	61.36	59.98	62.74	59.83	58.81	62.41	57.96	61.79
Al ₂ O ₃	23.21	23.62	23.61	24.85	25.55	23.98	25.37	26.81	24.1	26.43	24.19
K ₂ O	0.19	0.08	0.07	0.08	0.09	0.07	0.07	0.05	0.08	0.04	0.09
CaO	4.62	4.9	4.88	6.3	7.25	5.31	7.29	8.63	5.75	7.69	5.19
Na ₂ O	9	8.76	8.8	8.11	7.38	8.68	7.61	6.71	8.38	6.88	8.85
FeO	0.81	0.54	0.56	0.31	0.34	0.13	0.06	0.34	0.33	0.1	0.19
Total	101.41	101.48	101.05	101.01	100.59	100.91	100.23	101.35	101.05	99.1	100.3

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.78	2.78	2.77	2.70	2.70	2.70	2.66	2.60	2.74	2.61	2.74
Al	1.20	1.22	1.22	1.29	1.29	1.59	1.33	1.40	1.25	1.40	1.26
K	0.01	0.00	0.00	0.00	0.30	0.69	0.00	0.00	0.00	0.00	0.01
Ca	0.22	0.23	0.23	0.30	0.69	0.01	0.35	0.41	0.27	0.37	0.25
Na	0.76	0.74	0.75	0.69	0.01	0.00	0.66	0.57	0.71	0.60	0.76
Fe	0.03	0.02	0.02	0.01	0.00	0.00	0.00	0.01	0.01	0.00	0.01
% Ab	77.1	76.0	76.2	69.6	1.1	0.0	65.1	58.3	72.2	61.7	75.1
% An	21.9	23.5	23.4	29.9	69.2	1.6	34.5	41.4	27.4	38.1	24.4
% Or	1.1	0.5	0.4	0.5	29.7	98.4	0.4	0.3	0.5	0.2	0.5

MT98-135 Plagioclase (Continued)

Sample	P37	P38	P39	P40	P41	P42
SiO ₂	62.59	59.85	62.5	58.62	59.44	63.12
Al ₂ O ₃	23.98	26.27	23.94	26.93	26.12	23.91
K ₂ O	0.05	0.04	0.07	0.04	0.06	0.07
CaO	5.1	7.42	5.12	8.17	7.42	5.11
Na ₂ O	8.91	7.59	9.03	6.97	7.34	8.97
FeO	0.12	0.32	0.22	0.35	0.16	0.11
Total	100.75	101.49	100.88	101.08	100.54	101.29

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8
Si	2.75	2.63	2.75	2.60	2.64	2.76
Al	1.24	1.36	1.24	1.41	1.37	1.23
K	0.00	0.00	0.00	0.00	0.00	0.00
Ca	0.24	0.35	0.24	0.39	0.35	0.24
Na	0.76	0.65	0.77	0.60	0.63	0.76
Fe	0.00	0.01	0.01	0.01	0.01	0.00
% Ab	75.8	64.8	75.8	60.6	63.9	75.8
% An	24.0	35.0	23.8	39.2	35.7	23.8
% Or	0.3	0.2	0.4	0.2	0.3	0.4

MT98-135 Hornblende

Sample	H11	H12	H13	H14	H15	H16	H17	H18	H19	H20	H21
SiO ₂	40.60	42.06	41.83	42.41	41.98	41.62	41.90	41.70	43.01	42.84	42.21
Al ₂ O ₃	15.07	14.81	14.68	13.70	14.43	14.92	14.56	15.35	13.63	13.63	14.45
TiO ₂	0.19	0.35	0.27	0.35	0.31	0.29	0.30	0.30	0.25	0.36	0.28
Cr ₂ O ₃	0.00	0.01	0.00	0.00	0.02	0.05	0.04	0.02	0.02	0.01	0.02
FeO	19.50	18.41	18.00	18.20	18.14	18.44	18.29	18.65	17.57	18.00	17.51
MnO	0.21	0.31	0.27	0.32	0.22	0.31	0.27	0.25	0.27	0.27	0.25
K ₂ O	0.30	0.34	0.31	0.25	0.32	0.32	0.28	0.29	0.28	0.22	0.31
MgO	7.75	7.78	7.98	8.01	8.22	7.55	7.96	7.56	8.56	8.61	8.16
CaO	10.63	11.51	11.68	11.43	11.46	11.63	11.65	11.49	11.68	11.69	11.81
Na ₂ O	1.00	1.19	1.15	1.20	1.10	1.24	1.20	1.26	1.08	1.14	1.25
CL	0.02	0.03	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.00	0.02
F	0.02	0.04	0.03	0.09	0.03	0.00	0.06	0.01	0.05	0.02	0.03
Total	95.29	96.84	96.22	95.98	96.25	96.39	96.52	96.89	96.41	96.79	96.30

Number of cations in formula based on n oxygens

n	23	23	23	23	23	23	23	23	23	23	23
Si	6.28	6.37	6.37	6.48	6.39	6.34	6.37	6.32	6.51	6.47	6.41
Al iv	1.72	1.63	1.63	1.52	1.61	1.66	1.63	1.68	1.49	1.53	1.59
Al vi	1.03	1.02	1.00	0.94	0.98	1.02	0.98	1.06	0.94	0.90	0.99
Ti	0.02	0.04	0.03	0.04	0.04	0.03	0.03	0.03	0.03	0.04	0.03
Cr	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Fe	2.52	2.33	2.29	2.32	2.31	2.35	2.33	2.36	2.22	2.27	2.22
Mn	0.03	0.04	0.03	0.04	0.03	0.04	0.03	0.03	0.03	0.03	0.03
K	0.06	0.07	0.06	0.05	0.06	0.06	0.05	0.06	0.05	0.04	0.06
Mg	1.79	1.76	1.81	1.82	1.86	1.72	1.80	1.71	1.93	1.94	1.85
Ca	1.76	1.87	1.91	1.87	1.87	1.90	1.90	1.86	1.89	1.89	1.92
Na	0.30	0.35	0.34	0.36	0.32	0.37	0.35	0.37	0.32	0.33	0.37
Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F	0.01	0.02	0.01	0.04	0.01	0.00	0.03	0.00	0.02	0.01	0.01
Fe/Fe+Mg	0.59	0.57	0.56	0.56	0.55	0.58	0.56	0.58	0.54	0.54	0.55

MT98-135 Hornblende (Continued)

Sample	H22	H23	H24	H43	H44	H45	H46	H47	H48
SiO ₂	42.61	41.67	41.34	42.19	43.69	43.82	42.33	42.60	42.34
Al ₂ O ₃	14.44	14.94	14.78	13.92	13.12	13.44	14.31	13.98	14.75
TiO ₂	0.34	0.14	0.31	0.37	0.37	0.29	0.18	0.21	0.33
Cr ₂ O ₃	0.00	0.02	0.00	0.00	0.01	0.03	0.00	0.05	0.00
FeO	18.13	19.42	18.95	18.76	18.36	17.96	18.62	18.53	19.15
MnO	0.26	0.29	0.25	0.26	0.29	0.25	0.26	0.27	0.24
K ₂ O	0.26	0.31	0.36	0.32	0.27	0.29	0.26	0.28	0.27
MgO	8.16	7.16	7.32	8.13	8.51	8.54	7.76	7.75	7.72
CaO	11.73	11.73	11.60	11.50	11.67	11.77	11.86	11.61	11.61
Na ₂ O	1.19	1.19	1.08	1.25	1.10	1.10	1.11	1.08	1.17
CL	0.02	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00
F	0.05	0.04	0.02	0.08	0.08	0.05	0.01	0.01	0.08
Total	97.19	96.94	96.02	96.78	97.47	97.54	96.70	96.37	97.66

Number of cations in formula based on n oxygens

n	23	23	23	23	23	23	23	23	23
Si	6.42	6.34	6.34	6.41	6.56	6.56	6.42	6.48	6.38
Al iv	1.58	1.66	1.66	1.59	1.44	1.44	1.58	1.52	1.62
Al vi	0.98	1.02	1.01	0.91	0.88	0.93	0.98	0.98	0.99
Ti	0.04	0.02	0.04	0.04	0.04	0.03	0.02	0.02	0.04
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Fe	2.28	2.47	2.43	2.38	2.31	2.25	2.36	2.36	2.41
Mn	0.03	0.04	0.03	0.03	0.04	0.03	0.03	0.03	0.03
K	0.05	0.06	0.07	0.06	0.05	0.06	0.05	0.05	0.05
Mg	1.83	1.63	1.67	1.84	1.91	1.91	1.76	1.76	1.73
Ca	1.89	1.91	1.91	1.87	1.88	1.89	1.93	1.89	1.87
Na	0.35	0.35	0.32	0.37	0.32	0.32	0.33	0.32	0.34
Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F	0.02	0.02	0.01	0.04	0.04	0.02	0.00	0.00	0.04
Fe/Fe+Mg	0.55	0.60	0.59	0.56	0.55	0.54	0.57	0.57	0.58

MT98-137 Plagioclase

Sample	P13	P14	P15	P16	P17	P18	P19	P20	P21	P22	P23
SiO ₂	63.05	62.25	57.95	60.61	62.22	59.74	58.74	62.24	60.26	61.92	60.76
Al ₂ O ₃	23.8	24.23	26.55	24.99	24.08	23.76	25.84	23.6	24.74	23.65	24.96
K ₂ O	0.04	0.03	0.13	0.17	0.05	0.3	0.63	0.04	0.05	0.03	0.03
CaO	4.93	5.39	8.26	6.33	5.31	5.73	7.07	4.95	6.69	5.16	6.78
Na ₂ O	8.79	8.81	6.69	8.06	8.68	7.91	7.18	8.88	7.8	8.79	7.69
FeO	0.27	0.28	0.27	0.14	0.2	0.9	0.34	0.23	0.19	0.17	0.12
Total	100.88	100.99	99.85	100.3	100.54	98.34	99.8	99.94	99.73	99.72	100.34

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.77	2.74	2.60	2.69	2.75	2.71	2.63	2.76	2.69	2.75	2.69
Al	1.23	1.26	1.40	1.31	1.25	1.27	1.37	1.23	1.30	1.24	1.30
K	0.00	0.00	0.01	0.01	0.00	0.02	0.04	0.00	0.00	0.00	0.00
Ca	0.23	0.25	0.40	0.30	0.25	0.28	0.34	0.24	0.32	0.25	0.32
Na	0.75	0.75	0.58	0.69	0.74	0.70	0.62	0.76	0.68	0.76	0.66
Fe	0.01	0.01	0.01	0.01	0.01	0.03	0.01	0.01	0.01	0.01	0.00
%Ab	76.2	74.6	59.0	69.1	74.5	70.2	62.4	76.3	67.7	75.4	67.1
%An	23.6	25.2	40.3	30.0	25.2	28.1	34.0	23.5	32.1	24.5	32.7
%Or	0.2	0.2	0.8	1.0	0.3	1.8	3.6	0.2	0.3	0.2	0.2

MT98-137 Plagioclase (Continued)

Sample	P24	P25	P26	P27	P28	P29	P30	P31	P32	P33	P34
SiO ₂	60.55	61.6	60.09	62.5	60.19	63.2	57.96	58.68	61.71	61.02	60.49
Al ₂ O ₃	24.74	23.62	24.09	23.22	24.72	23.08	26.75	26.63	24.42	25.59	25.05
K ₂ O	0.03	0.06	0.06	0.1	0.03	0.03	0.03	0.02	0.04	0.02	0.04
CaO	6.61	5.24	6.09	4.79	6.51	4.38	8.38	8.17	5.75	6.63	6.57
Na ₂ O	7.73	8.79	8.16	8.94	7.93	9.34	6.79	6.99	8.53	8.01	7.85
FeO	0.42	0.26	0.88	0.21	0.27	0.18	0.28	0.16	0.14	0.1	0.13
Total	100.08	99.57	99.37	99.76	99.65	100.21	100.19	100.65	100.59	101.37	100.13

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.69	2.75	2.70	2.78	2.69	2.79	2.59	2.61	2.73	2.68	2.69
Al	1.30	1.24	1.28	1.22	1.30	1.20	1.41	1.39	1.27	1.32	1.31
K	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ca	0.32	0.25	0.29	0.23	0.31	0.21	0.40	0.39	0.27	0.31	0.31
Na	0.67	0.76	0.71	0.77	0.69	0.80	0.59	0.60	0.73	0.68	0.68
Fe	0.02	0.01	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00
%Ab	67.8	75.0	70.6	76.7	68.7	79.3	59.4	60.7	72.7	68.5	68.2
%An	32.0	24.7	29.1	22.7	31.2	20.5	40.5	39.2	27.1	31.3	31.6
%Or	0.2	0.3	0.3	0.6	0.2	0.2	0.2	0.1	0.2	0.1	0.2

MT98-137 Plagioclase (Continued)

Sample	P35	P36	P37	P38	P39	P40	P41	P42
SiO ₂	62.75	52.7	59.45	61.41	58.1	62.42	58.78	62.69
Al ₂ O ₃	23.48	30.16	25.79	24.47	26.87	23.56	25.57	23.56
K ₂ O	0.03	0.03	0.04	0.04	0.03	0.05	0.02	0.03
CaO	4.74	12.81	7.41	5.76	8.67	4.88	8.77	4.61
Na ₂ O	9.08	4.24	7.69	8.61	6.67	8.9	6.42	9.03
FeO	0.32	0.18	0.19	0.13	0.12	0.09	0.86	0.14
Total	100.4	100.12	100.57	100.42	100.46	99.9	100.42	100.06

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8
Si	2.77	2.39	2.64	2.72	2.59	2.77	2.63	2.77
Al	1.22	1.61	1.35	1.28	1.41	1.23	1.35	1.23
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ca	0.22	0.62	0.35	0.27	0.41	0.23	0.42	0.22
Na	0.78	0.37	0.66	0.74	0.58	0.76	0.56	0.77
Fe	0.01	0.01	0.01	0.00	0.00	0.00	0.03	0.01
% Ab	77.5	37.4	65.1	72.8	58.1	76.5	56.9	77.9
% An	22.4	62.4	34.7	26.9	41.7	23.2	43.0	22.0
% Or	0.2	0.2	0.2	0.2	0.2	0.3	0.1	0.2

MT98-137 Hornblende

Sample	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11
SiO ₂	42.89	42.18	42.88	42.93	42.84	42.96	45.45	44.29	42.28	42.12	42.66
Al ₂ O ₃	14.63	15.32	15.26	14.10	15.25	14.63	12.48	13.12	14.67	14.25	14.72
TiO ₂	0.34	0.37	0.27	0.38	0.11	0.34	0.24	0.49	0.29	0.27	0.27
Cr ₂ O ₃	0.06	0.03	0.00	0.09	0.01	0.10	0.03	0.06	0.07	0.05	0.07
FeO	18.82	18.89	18.22	18.98	18.74	19.27	16.83	17.76	19.55	19.49	19.08
MnO	0.29	0.26	0.12	0.28	0.26	0.23	0.18	0.21	0.20	0.20	0.27
K ₂ O	0.22	0.24	0.12	0.19	0.17	0.22	0.08	0.29	0.21	0.22	0.20
MgO	7.58	6.92	7.52	7.62	7.34	7.75	9.12	8.39	7.56	7.33	7.29
CaO	11.28	11.48	11.85	11.27	11.50	11.52	11.46	11.45	11.21	11.23	11.33
Na ₂ O	1.34	1.27	1.20	1.32	1.27	1.25	1.00	1.14	1.38	1.31	1.20
Cl	0.02	0.03	0.03	0.01	0.01	0.01	0.04	0.02	0.00	0.01	0.02
F	0.02	0.02	0.00	0.00	0.06	0.00	0.02	0.06	0.00	0.01	0.07
Total	97.49	97.01	97.47	97.17	97.56	98.28	96.93	97.28	97.42	96.49	97.18

Number of cations in formula based on n oxygens

n	23	23	23	23	23	23	23	23	23	23	23
Si	6.45	6.38	6.42	6.48	6.43	6.42	6.77	6.63	6.39	6.43	6.44
Al iv	1.55	1.62	1.58	1.52	1.57	1.58	1.23	1.37	1.61	1.57	1.56
Al vi	1.04	1.11	1.11	0.99	1.12	0.99	0.96	0.94	1.00	0.99	1.06
Ti	0.04	0.04	0.03	0.04	0.01	0.04	0.03	0.06	0.03	0.03	0.03
Cr	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.01	0.01	0.01	0.01
Fe	2.37	2.39	2.28	2.40	2.35	2.41	2.09	2.22	2.47	2.49	2.41
Mn	0.04	0.03	0.02	0.04	0.03	0.03	0.02	0.03	0.03	0.03	0.03
K	0.04	0.05	0.02	0.04	0.03	0.04	0.02	0.06	0.04	0.04	0.04
Mg	1.70	1.56	1.68	1.71	1.64	1.73	2.02	1.87	1.70	1.67	1.64
Ca	1.82	1.86	1.90	1.82	1.85	1.84	1.83	1.84	1.81	1.84	1.83
Na	0.39	0.37	0.35	0.39	0.37	0.36	0.29	0.33	0.40	0.39	0.35
Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F	0.01	0.01	0.00	0.00	0.03	0.00	0.01	0.03	0.00	0.00	0.03
Fe/Fe+Mg	0.58	0.60	0.58	0.58	0.59	0.58	0.51	0.54	0.59	0.60	0.59

MT98-137 Hornblende (Continued)

Sample	H12	H43	H44	H45	H46	H47	H48	H49	H50
SiO ₂	42.76	46.70	46.66	45.59	41.60	43.41	41.76	45.20	47.77
Al ₂ O ₃	14.45	10.65	10.67	11.47	16.55	14.75	14.92	11.86	8.55
TiO ₂	0.25	0.26	0.38	0.44	0.25	0.32	0.36	0.22	0.39
Cr ₂ O ₃	0.10	0.04	0.00	0.10	0.00	0.07	0.10	0.04	0.05
FeO	19.36	16.65	16.45	16.51	18.37	17.35	19.18	17.30	16.64
MnO	0.13	0.11	0.27	0.29	0.23	0.27	0.25	0.29	0.29
K ₂ O	0.22	0.05	0.06	0.04	0.17	0.12	0.21	0.07	0.03
MgO	7.36	10.24	10.09	9.64	6.96	8.36	6.98	9.22	11.00
CaO	11.22	11.84	11.80	11.55	11.73	11.66	11.24	11.80	11.64
Na ₂ O	1.33	0.98	0.92	1.06	1.33	1.19	1.39	1.10	0.78
CL	0.01	0.04	0.04	0.10	0.11	0.05	0.00	0.01	0.00
F	0.01	0.06	0.02	0.04	0.00	0.03	0.06	0.05	0.06
Total	97.20	97.62	97.36	96.83	97.30	97.58	96.45	97.16	97.20

Number of cations in formula based on n oxygens

n	23	23	23	23	23	23	23	23	23
Si	6.46	6.90	6.91	6.80	6.26	6.47	6.37	6.75	7.08
Al iv	1.54	1.10	1.09	1.20	1.74	1.53	1.63	1.25	0.92
Al vi	1.03	0.76	0.77	0.82	1.20	1.06	1.06	0.84	0.58
Ti	0.03	0.03	0.04	0.05	0.03	0.04	0.04	0.02	0.04
Cr	0.01	0.00	0.00	0.01	0.00	0.01	0.01	0.00	0.01
Fe	2.44	2.06	2.04	2.06	2.31	2.16	2.45	2.16	2.06
Mn	0.02	0.01	0.03	0.04	0.03	0.03	0.03	0.04	0.04
K	0.04	0.01	0.01	0.01	0.03	0.02	0.04	0.01	0.01
Mg	1.66	2.26	2.23	2.14	1.56	1.86	1.59	2.05	2.43
Ca	1.82	1.87	1.87	1.85	1.89	1.86	1.84	1.89	1.85
Na	0.39	0.28	0.26	0.31	0.39	0.34	0.41	0.32	0.22
Cl	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00
F	0.00	0.03	0.01	0.02	0.00	0.01	0.03	0.02	0.03
Fe/Fe+Mg	0.60	0.48	0.48	0.49	0.60	0.54	0.61	0.51	0.46

MT98-157 Plagioclase

Sample	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
SiO ₂	60.94	61.21	61.31	60.25	60.31	60.10	59.76	61.99	59.31	59.95	60.45
Al ₂ O ₃	24.56	25.02	24.89	25.69	25.51	25.74	26.16	24.76	26.61	24.52	26.30
K ₂ O	0.08	0.05	0.05	0.06	0.05	0.05	0.05	0.04	0.07	0.09	0.04
CaO	6.22	6.38	6.34	7.48	6.97	7.37	7.68	5.94	8.23	7.00	7.74
Na ₂ O	7.92	8.01	8.04	7.45	7.70	7.32	7.14	8.25	7.03	7.64	7.33
FeO	0.91	0.32	0.28	0.44	0.45	0.37	0.24	0.34	0.16	0.85	0.19
Total	100.63	100.99	100.91	101.37	100.99	100.95	101.03	101.32	101.41	100.05	102.05

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.70	2.70	2.70	2.65	2.66	2.66	2.64	2.72	2.61	2.68	2.64
Al	1.28	1.30	1.29	1.33	1.33	1.34	1.36	1.28	1.38	1.29	1.36
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Ca	0.30	0.30	0.30	0.35	0.33	0.35	0.36	0.28	0.39	0.34	0.36
Na	0.68	0.68	0.69	0.64	0.66	0.63	0.61	0.70	0.60	0.66	0.62
Fe	0.03	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.03	0.01
% Ab	69.4	69.2	69.5	64.1	66.5	64.1	62.5	71.4	60.5	66.0	63.0
% An	30.1	30.5	30.3	35.6	33.2	35.6	37.2	28.4	39.1	33.4	36.8
% Or	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.4	0.5	0.2

MT98-157 Plagioclase (Continued)

Sample	P27	P28	P29	P30	P31	P32	P33	P34	P35	P36	P37
SiO ₂	60.10	61.19	60.19	59.08	60.54	60.40	59.05	60.08	62.60	61.24	61.64
Al ₂ O ₃	26.16	25.14	25.74	26.73	25.73	25.96	26.65	25.84	24.15	25.59	25.01
K ₂ O	0.05	0.03	0.05	0.05	0.05	0.05	0.04	0.06	0.06	0.09	0.05
CaO	7.50	6.56	7.20	8.00	7.19	7.73	8.16	6.98	5.34	6.95	6.04
Na ₂ O	7.02	8.07	7.43	7.06	7.51	7.38	7.02	7.49	8.69	7.62	8.09
FeO	0.26	0.12	0.59	0.24	0.23	0.22	0.31	0.35	0.34	0.31	0.40
Total	101.09	101.11	101.20	101.16	101.25	101.74	101.23	100.80	101.18	101.80	101.23

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.65	2.69	2.66	2.61	2.66	2.65	2.61	2.66	2.75	2.68	2.71
Al	1.36	1.30	1.34	1.39	1.33	1.34	1.39	1.35	1.25	1.32	1.29
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Ca	0.35	0.31	0.34	0.38	0.34	0.36	0.39	0.33	0.25	0.33	0.28
Na	0.60	0.69	0.64	0.60	0.64	0.63	0.60	0.64	0.74	0.65	0.69
Fe	0.01	0.00	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
% Ab	62.7	68.9	64.9	61.3	65.2	63.2	60.7	65.8	74.4	66.1	70.6
% An	37.0	30.9	34.8	38.4	34.5	36.6	39.0	33.9	25.3	33.3	29.1
% Or	0.3	0.2	0.3	0.3	0.3	0.3	0.2	0.3	0.3	0.5	0.3

MT98-157 Plagioclase (Continued)

Sample	P38
SiO ₂	60.44
Al ₂ O ₃	25.66
K ₂ O	0.06
CaO	6.90
Na ₂ O	7.68
FeO	0.23
Total	100.97

Number of cations in formula based on n oxygens
n 8

Si	2.67
Al	1.33
K	0.00
Ca	0.33
Na	0.66
Fe	0.01
% Ab	66.6
% An	33.1
% Or	0.3

MT98-157 Hornblende

Sample	H12	H13	H14	H15	H16	H17	H18	H19	H20	H23	H24
SiO ₂	44.32	45.93	45.90	45.84	45.93	43.78	43.77	44.20	45.73	46.67	46.00
Al ₂ O ₃	12.97	11.75	10.38	10.56	10.85	12.99	12.84	12.94	11.19	10.20	10.34
TiO ₂	0.27	0.22	0.29	0.25	0.19	0.29	0.34	0.15	0.15	0.27	0.34
Cr ₂ O ₃	0.07	0.00	0.00	0.11	0.04	0.00	0.12	0.01	0.01	0.01	0.05
FeO	17.27	16.44	15.93	16.58	15.80	16.55	17.16	17.39	16.28	15.84	16.11
MnO	0.30	0.26	0.26	0.31	0.28	0.29	0.33	0.27	0.26	0.29	0.35
K ₂ O	0.14	0.09	0.05	0.10	0.05	0.17	0.11	0.09	0.07	0.05	0.03
MgO	8.98	9.92	10.69	10.34	10.39	9.50	9.10	8.73	9.89	10.78	10.50
CaO	11.98	11.79	12.07	12.03	12.00	12.12	11.88	12.02	12.13	12.18	12.30
Na ₂ O	1.26	1.09	1.00	0.91	0.93	1.24	1.28	1.19	1.03	0.88	0.97
Cl	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F	0.02	0.07	0.07	0.02	0.03	0.05	0.05	0.06	0.06	0.05	0.02
Total	97.58	97.56	96.64	97.06	96.49	96.98	96.98	97.05	96.8	97.22	97.01

Number of cations in formula based on n oxygens

n	23	23	23	23	23	23	23	23	23	23	23
Si	6.61	6.80	6.86	6.84	6.86	6.56	6.57	6.63	6.83	6.91	6.85
Al iv	1.39	1.20	1.14	1.16	1.14	1.44	1.43	1.37	1.17	1.09	1.15
Al vi	0.89	0.84	0.68	0.69	0.76	0.85	0.85	0.91	0.79	0.69	0.67
Ti	0.03	0.02	0.03	0.03	0.02	0.03	0.04	0.02	0.02	0.03	0.04
Cr	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.01
Fe	2.15	2.03	1.99	2.07	1.97	2.07	2.16	2.18	2.03	1.96	2.01
Mn	0.04	0.03	0.03	0.04	0.04	0.04	0.04	0.03	0.03	0.04	0.04
K	0.03	0.02	0.01	0.02	0.01	0.03	0.02	0.02	0.01	0.01	0.01
Mg	2.00	2.19	2.38	2.30	2.31	2.12	2.04	1.95	2.20	2.38	2.33
Ca	1.91	1.87	1.93	1.92	1.92	1.95	1.91	1.93	1.94	1.93	1.96
Na	0.36	0.31	0.29	0.26	0.27	0.36	0.37	0.35	0.30	0.25	0.28
Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F	0.01	0.03	0.03	0.01	0.01	0.02	0.02	0.03	0.03	0.02	0.01
Fe/Fe+Mg	0.52	0.48	0.46	0.47	0.46	0.49	0.51	0.53	0.48	0.45	0.46

MT98-157 Homblende (Continued)

Sample	H39	H40	H41	H42
SiO ₂	44.05	43.76	45.03	44.24
Al ₂ O ₃	12.90	12.68	11.91	12.33
TiO ₂	0.31	0.38	0.29	0.32
Cr ₂ O ₃	0.00	0.05	0.03	0.03
FeO	17.71	18.11	16.67	17.50
MnO	0.24	0.27	0.37	0.17
K ₂ O	0.15	0.21	0.16	0.17
MgO	9.03	8.83	9.80	9.28
CaO	12.03	11.75	11.99	11.74
Na ₂ O	1.38	1.23	1.05	1.20
CL	0.00	0.00	0.00	0.00
F	0.04	0.05	0.00	0.01
Total	97.84	97.32	97.30	96.99

Number of cations in formula based on n oxygens

n	23	23	23	23
Si	6.57	6.58	6.71	6.64
Al iv	1.43	1.42	1.29	1.36
Al vi	0.84	0.82	0.80	0.82
Ti	0.03	0.04	0.03	0.04
Cr	0.00	0.01	0.00	0.00
Fe	2.21	2.28	2.08	2.20
Mn	0.03	0.03	0.05	0.02
K	0.03	0.04	0.03	0.03
Mg	2.01	1.98	2.18	2.08
Ca	1.92	1.89	1.91	1.89
Na	0.40	0.36	0.30	0.35
Cl	0.00	0.00	0.00	0.00
F	0.02	0.02	0.00	0.00
Fe/Fe+Mg	0.52	0.53	0.49	0.51

BLB97-003a Plagioclase

Sample	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29
SiO ₂	54.81	59.58	57.75	59.82	61.72	57.1	61.51	64.83	52.79	58.38	59.86
Al ₂ O ₃	29.92	26.17	27.4	26.24	24.92	27.98	25.24	23.09	29.44	27.21	25.79
K ₂ O	0.01	0.02	0.08	0.03	0.07	0.02	0.03	0.05	0.02	0.02	0.04
CaO	11.89	7.58	8.57	7.53	5.51	9.84	6.46	3.75	11.7	8.76	7.37
Na ₂ O	4.82	7.64	6.85	7.61	8.68	6.14	8.24	9.98	4.91	6.93	7.87
FeO	0.27	0.15	0.08	0.09	0.28	0.19	0.08	0.03	0.22	0.15	0.05
SrO	-	-	-	-	-	-	-	-	-	-	-
BaO	-	-	-	-	-	-	-	-	-	-	-
Total	101.72	101.14	100.73	101.32	101.18	101.27	101.56	101.73	99.08	101.45	100.98

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.43	2.63	2.57	2.64	2.71	2.53	2.69	2.82	2.41	2.58	2.65
Al	1.57	1.36	1.44	1.36	1.29	1.46	1.30	1.18	1.59	1.42	1.34
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ca	0.57	0.36	0.41	0.36	0.26	0.47	0.30	0.17	0.57	0.41	0.35
Na	0.41	0.65	0.59	0.65	0.74	0.53	0.70	0.84	0.43	0.59	0.67
Fe	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.00
Sr	-	-	-	-	-	-	-	-	-	-	-
Ba	-	-	-	-	-	-	-	-	-	-	-
% Ab	42.3	64.5	58.9	64.5	73.7	53.0	69.7	82.6	43.1	58.8	65.8
% An	57.7	35.4	40.7	35.3	25.9	46.9	30.2	17.1	56.8	41.1	34.0
% Or	0.1	0.1	0.5	0.2	0.4	0.1	0.2	0.3	0.1	0.1	0.2

BLB97-003a Plagioclase (continued)

Sample	P52	P53	P54	P55	P56	P57	P58	P59	P60	P61	P62
SiO ₂	51.79	54.11	53.13	53.98	54.34	53.33	54.19	52.08	57.55	55.16	61.38
Al ₂ O ₃	31.2	30.2	30.07	30.58	29.4	28.46	30.55	31.93	27.67	29.23	25.51
K ₂ O	0.05	0.04	0.04	0.03	0.04	0.03	0.06	0.04	0.03	0.03	0.04
CaO	13.49	12.03	12.55	12.4	11.12	10.64	12.37	13.73	9.14	10.92	6.35
Na ₂ O	3.74	4.78	4.43	4.61	5.39	5.35	4.57	3.6	6.6	5.35	8.21
FeO	0.62	0.44	0.52	0.44	0.36	0.26	0.31	0.2	0.5	0.37	0.36
SrO	-	-	-	-	-	-	-	-	-	-	-
BaO	-	-	-	-	-	-	-	-	-	-	-
Total	100.89	101.6	100.74	102.04	100.65	98.07	102.05	101.58	101.49	101.06	101.85

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.34	2.41	2.39	2.40	2.44	2.45	2.40	2.33	2.55	2.46	2.68
Al	1.66	1.59	1.60	1.60	1.56	1.54	1.60	1.68	1.44	1.54	1.31
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ca	0.65	0.57	0.61	0.59	0.54	0.52	0.59	0.66	0.43	0.52	0.30
Na	0.33	0.41	0.39	0.40	0.47	0.48	0.39	0.31	0.57	0.46	0.70
Fe	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.01	0.01
Sr	-	-	-	-	-	-	-	-	-	-	-
Ba	-	-	-	-	-	-	-	-	-	-	-
% Ab	33.3	41.7	38.9	40.1	46.6	47.6	39.9	32.1	56.6	46.9	69.9
% An	66.4	58.0	60.9	59.7	53.2	52.3	59.7	67.7	43.3	52.9	29.9
% Or	0.3	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.2

BLB97-003a Plagioclase (continued)

Sample	P63	P64	P65	P66	P67	P95	P96	P97	P98	P99	P100
SiO ₂	54.72	51.88	55.82	57.39	57.18	55.91	59.81	60.28	55.01	61.79	64.65
Al ₂ O ₃	30.06	31.94	28.57	28.17	27.53	29.41	26.8	26.58	29.52	24.71	23.39
K ₂ O	0.04	0.03	0.32	0.04	0.07	0.38	0.04	0.05	0.32	1.56	0.08
CaO	11.45	13.91	10.68	9.52	8.88	10.36	7.99	7.36	11.12	5.49	4.23
Na ₂ O	5.1	3.74	5.4	6.46	6.64	5.47	7.07	7.44	4.78	7.21	9.31
FeO	0.4	0.4	0.6	0.36	0.45	0.23	0.16	0.12	0.33	0.14	0.16
SrO	-	-	-	-	-	-	-	-	-	-	-
BaO	-	-	-	-	-	-	-	-	-	-	-
Total	101.77	101.9	101.39	101.94	100.75	101.76	101.87	101.83	101.08	100.9	101.82

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.43	2.32	2.49	2.53	2.55	2.48	2.62	2.64	2.46	2.73	2.80
Al	1.57	1.68	1.50	1.46	1.45	1.53	1.38	1.37	1.55	1.29	1.20
K	0.00	0.00	0.02	0.00	0.00	0.02	0.00	0.00	0.02	0.09	0.00
Ca	0.54	0.67	0.51	0.45	0.42	0.49	0.38	0.35	0.53	0.26	0.20
Na	0.44	0.32	0.47	0.55	0.57	0.47	0.60	0.63	0.41	0.62	0.78
Fe	0.01	0.01	0.02	0.01	0.02	0.01	0.01	0.00	0.01	0.01	0.01
Sr	-	-	-	-	-	-	-	-	-	-	-
Ba	-	-	-	-	-	-	-	-	-	-	-
%Ab	44.5	32.7	46.9	55.0	57.3	47.8	61.4	64.5	42.9	64.0	79.6
%An	55.2	67.2	51.3	44.8	42.3	50.0	38.4	35.2	55.2	26.9	20.0
%Or	0.2	0.2	1.8	0.2	0.4	2.2	0.2	0.3	1.9	9.1	0.4

BLB97-003a Plagioclase (continued)

Sample	P101	P102	P103	P104	P105	P106	P124	P125	P126	P127	P128
SiO ₂	55.6	61.15	55.82	61.8	53.8	60.1	58.56	59	60.24	55.32	59.15
Al ₂ O ₃	29.73	25.43	29.45	25.66	25.22	26.65	25.71	25.46	24.83	28.79	25.19
K ₂ O	0.45	0.05	0.04	0.04	0.12	0.04	0.03	0.03	0.04	0.02	0.01
CaO	10.37	6.64	11.09	6.74	10.8	8.02	6.5	6.29	5.51	10.95	6.49
Na ₂ O	5.32	8.01	5.56	7.93	4.89	7.22	7.39	7.8	8.3	5.39	7.79
FeO	0.33	0.21	0.09	0.16	3.19	0.34	0.39	0.16	0.1	0.18	0.08
SrO	-	-	-	-	-	-	-	-	-	-	-
BaO	-	-	-	-	-	-	-	-	-	-	-
Total	101.8	101.49	102.05	102.33	98.02	102.37	98.58	98.74	99.02	100.65	98.71

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.46	2.68	2.47	2.69	2.51	2.62	2.65	2.66	2.70	2.48	2.67
Al	1.55	1.31	1.53	1.31	1.39	1.37	1.37	1.35	1.31	1.52	1.34
K	0.03	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Ca	0.49	0.31	0.52	0.31	0.54	0.38	0.31	0.30	0.26	0.53	0.31
Na	0.46	0.68	0.48	0.67	0.44	0.61	0.65	0.68	0.72	0.47	0.68
Fe	0.01	0.01	0.00	0.01	0.12	0.01	0.01	0.01	0.00	0.01	0.00
Sr	-	-	-	-	-	-	-	-	-	-	-
Ba	-	-	-	-	-	-	-	-	-	-	-
%Ab	46.9	68.4	47.5	67.9	44.7	61.8	67.2	69.1	73.0	47.1	68.4
%An	50.5	31.3	52.3	31.9	54.6	38.0	32.6	30.8	26.8	52.8	31.5
%Or	2.6	0.3	0.2	0.2	0.7	0.2	0.2	0.2	0.2	0.1	0.1

BLB97-003a Plagioclase (continued)

Sample	P129	P130	P131	P132	P133	P134	P135	P158	P159	P160	P161
SiO ₂	58.85	57.15	64.42	54.83	59.46	58.88	59.32	54.95	53.48	58.17	51.69
Al ₂ O ₃	25.58	26.72	22.78	27.97	24.99	25.14	25.2	29.85	29.33	26.89	30.54
K ₂ O	0.03	0.04	0.02	0.22	0.04	0.04	0.04	0.04	0.05	0.08	0.14
CaO	6.64	7.98	3.2	9.58	5.92	6.56	6.19	11.97	10.63	8.73	12.25
Na ₂ O	7.58	6.79	9.96	5.71	8.03	7.63	8.16	4.83	5.06	6.64	4.24
FeO	0.08	0.18	0.03	0.08	0.09	0.18	0.15	0.3	0.22	0.21	0.65
SrO	-	-	-	-	-	-	-	-	-	-	-
BaO	-	-	-	-	-	-	-	-	-	-	-
Total	98.76	98.86	100.41	98.39	98.53	98.43	99.06	101.94	98.77	100.72	99.51

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.65	2.59	2.83	2.50	2.68	2.66	2.67	2.44	2.44	2.59	2.36
Al	1.36	1.42	1.18	1.51	1.33	1.34	1.34	1.56	1.58	1.41	1.64
K	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Ca	0.32	0.39	0.15	0.47	0.29	0.32	0.30	0.57	0.52	0.42	0.60
Na	0.66	0.60	0.85	0.51	0.70	0.67	0.71	0.42	0.45	0.57	0.38
Fe	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.02
Sr	-	-	-	-	-	-	-	-	-	-	-
Ba	-	-	-	-	-	-	-	-	-	-	-
% Ah	67.3	60.5	84.8	51.2	70.9	67.6	70.3	42.1	46.1	57.7	38.2
% An	32.6	39.3	15.1	47.5	28.9	32.1	29.5	57.7	53.6	41.9	61.0
% Or	0.2	0.2	0.1	1.3	0.2	0.2	0.2	0.2	0.3	0.5	0.8

BLB97-003a Plagioclase (continued)

Sample	P162	P163	P164	P165	P166	P167	P168	P169	P170	P171	P172
SiO ₂	54.21	50.43	52.04	53.98	55.13	54.87	54.55	55.03	53.70	52.58	57.21
Al ₂ O ₃	29.32	31.22	29.41	29.79	27.46	27.54	28.16	28.06	28.04	29.28	26.49
K ₂ O	0.05	0.04	0.04	0.04	0.04	0.06	0.04	0.18	0.10	0.04	0.02
CaO	11.91	13.28	11.15	12.11	10.02	10.12	10.60	10.46	10.89	11.98	8.52
Na ₂ O	4.75	3.68	4.85	4.8	5.37	5.32	5.23	5.19	4.91	4.39	6.39
FeO	0.51	0.45	0.31	0.36	0.19	0.22	0.22	0.22	0.19	0.14	0.18
SrO	-	-	-	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BaO	-	-	-	-	0.04	0.00	0.00	0.13	0.04	0.00	0.06
Total	100.75	99.1	98.4	101.08	98.25	98.12	98.81	99.27	97.86	98.41	98.88

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.44	2.32	2.42	2.42	2.52	2.51	2.49	2.50	2.47	2.42	2.59
Al	1.55	1.69	1.59	1.57	1.48	1.49	1.51	1.50	1.52	1.58	1.41
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00
Ca	0.57	0.65	0.55	0.58	0.49	0.50	0.52	0.51	0.54	0.59	0.41
Na	0.41	0.33	0.43	0.42	0.48	0.47	0.46	0.46	0.44	0.39	0.56
Fe	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Sr	-	-	-	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	-	-	-	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00
%Ab	41.8	33.3	43.9	41.7	49.1	48.6	47.1	46.8	44.6	39.7	57.5
%An	57.9	66.4	55.8	58.1	50.6	51.1	52.7	52.1	54.8	60.0	42.4
%Or	0.3	0.2	0.2	0.2	0.2	0.3	0.2	1.1	0.6	0.3	0.1

BLB97-003a Plagioclase (continued)

Sample	P173	P174	P175	P176	P177	P178	P179	P180	P181	P182	P184
SiO ₂	56.86	50.11	48.19	53.32	53.23	53.75	54.33	53.16	62.05	58.80	57.97
Al ₂ O ₃	26.69	31.10	32.15	24.82	29.98	28.94	28.69	29.74	23.04	25.14	25.79
K ₂ O	0.02	0.65	2.27	1.23	0.02	0.04	0.02	0.05	0.04	0.04	0.03
CaO	8.74	12.84	11.59	7.27	11.99	11.47	11.46	12.10	4.89	7.20	7.84
Na ₂ O	6.21	3.50	2.27	5.93	4.49	4.74	4.79	4.32	8.63	7.15	6.66
FeO	0.06	1.26	0.71	2.78	0.12	0.19	0.19	0.09	0.07	0.06	0.02
SrO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BaO	0.00	0.05	0.00	0.04	0.03	0.00	0.02	0.19	0.00	0.00	0.14
Total	98.58	99.51	97.18	95.39	99.87	99.13	99.51	99.65	98.73	98.40	98.44

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.58	2.31	2.27	2.55	2.41	2.45	2.46	2.41	2.78	2.66	2.63
Al	1.43	1.69	1.78	1.40	1.60	1.55	1.53	1.59	1.22	1.34	1.38
K	0.00	0.04	0.14	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ca	0.42	0.63	0.58	0.37	0.58	0.56	0.56	0.59	0.23	0.35	0.38
Na	0.55	0.31	0.21	0.55	0.39	0.42	0.42	0.38	0.75	0.63	0.59
Fe	0.00	0.05	0.03	0.11	0.00	0.01	0.01	0.00	0.00	0.00	0.00
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
% Ab	56.2	31.7	22.3	55.1	40.3	42.7	43.0	39.1	76.0	64.1	60.5
% An	43.7	64.4	63.0	37.3	59.5	57.1	56.9	60.6	23.8	35.7	39.3
% Or	0.1	3.9	14.7	7.5	0.1	0.2	0.1	0.3	0.2	0.3	0.2

BLB97-003a Plagioclase (continued)

Sample	P186	P187	P188	P189	P190	P193	P194	P195	P196	P197	P198
SiO ₂	59.55	55.87	53.51	55.77	58.68	53.87	63.42	63.53	64.35	62.87	60.21
Al ₂ O ₃	24.40	27.59	28.63	27.55	25.34	22.13	22.51	22.24	22.70	22.20	23.63
K ₂ O	0.05	0.04	0.10	0.05	0.04	7.77	0.04	0.06	0.03	0.04	0.17
CaO	6.53	9.73	11.52	9.66	7.47	5.31	3.87	3.70	3.68	3.78	5.83
Na ₂ O	7.39	5.72	4.76	5.67	6.85	0.80	8.58	8.99	8.87	8.85	7.79
FeO	0.07	0.18	0.10	0.22	0.01	3.18	0.69	0.29	0.33	0.60	0.80
SrO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BaO	0.00	0.00	0.00	0.00	0.23	1.06	0.00	0.00	0.00	0.00	0.07
Total	98.00	99.13	98.62	98.92	98.63	94.11	99.10	98.80	99.96	98.33	98.51

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.70	2.53	2.45	2.53	2.65	2.68	2.82	2.83	2.83	2.82	2.72
Al	1.30	1.47	1.54	1.47	1.35	1.30	1.18	1.17	1.18	1.17	1.26
K	0.00	0.00	0.01	0.00	0.00	0.49	0.00	0.00	0.00	0.00	0.01
Ca	0.32	0.47	0.57	0.47	0.36	0.28	0.18	0.18	0.17	0.18	0.28
Na	0.65	0.50	0.42	0.50	0.60	0.08	0.74	0.78	0.76	0.77	0.68
Fe	0.00	0.01	0.00	0.01	0.00	0.13	0.03	0.01	0.01	0.02	0.03
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.01	0.04	0.00	0.00	0.00	0.00	0.00
% Ab	67.0	51.4	42.5	51.4	62.3	9.0	79.9	81.2	81.2	80.7	70.0
% An	32.7	48.4	56.9	48.3	37.5	33.2	19.9	18.5	18.6	19.0	28.9
% Or	0.3	0.3	0.6	0.3	0.3	57.8	0.2	0.3	0.2	0.2	1.0

BLB97-003a Plagioclase (continued)

Sample	P199	P201	P202	P203	P204	P205	P206	P207	P208	P209	P210
SiO ₂	55.20	56.90	56.62	57.73	50.24	54.64	54.58	55.12	56.95	56.35	57.05
Al ₂ O ₃	24.57	22.65	22.79	22.70	20.76	28.30	28.56	27.59	27.27	26.72	26.52
K ₂ O	0.10	0.03	0.04	0.08	4.34	0.00	0.04	0.14	0.03	0.02	0.01
CaO	9.81	5.49	5.47	5.45	4.49	10.22	10.45	9.88	8.65	8.74	8.51
Na ₂ O	6.32	8.05	7.62	8.24	2.67	5.83	5.51	5.98	6.81	6.64	7.02
FeO	2.11	5.61	6.94	5.66	13.25	0.49	0.04	0.17	0.11	0.37	0.29
SrO	0.00	0.00	0.00	0.02	0.00	0.08	0.06	0.08	0.02	0.02	0.00
BaO	0.00	0.04	0.00	0.00	0.61	0.00	0.00	0.11	0.06	0.00	0.00
Total	98.11	98.77	99.48	99.88	96.34	99.56	99.24	99.08	99.92	98.85	99.41

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.56	2.64	2.62	2.65	2.54	2.48	2.48	2.51	2.56	2.56	2.58
Al	1.34	1.24	1.24	1.23	1.24	1.51	1.53	1.48	1.44	1.43	1.41
K	0.01	0.00	0.00	0.00	0.28	0.00	0.00	0.01	0.00	0.00	0.00
Ca	0.49	0.27	0.27	0.27	0.24	0.50	0.51	0.48	0.42	0.43	0.41
Na	0.57	0.72	0.69	0.73	0.26	0.51	0.49	0.53	0.59	0.58	0.61
Fe	0.08	0.22	0.27	0.22	0.56	0.02	0.00	0.01	0.00	0.01	0.01
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
%Ab	53.5	72.5	71.4	72.9	33.3	50.8	48.7	51.9	58.6	57.8	59.8
%An	45.9	27.3	28.3	26.6	31.0	49.2	51.1	47.3	41.2	42.1	40.1
%Or	0.5	0.2	0.2	0.5	35.7	0.0	0.2	0.8	0.2	0.1	0.1

BLB97-003a Plagioclase (continued)

Sample	P211	P212	P213	P214	P215	P216	P217	P218	P219	P220	P221
SiO ₂	55.98	58.21	58.60	57.73	57.78	58.31	58.89	59.18	56.74	58.75	58.75
Al ₂ O ₃	27.46	25.55	25.26	26.29	26.53	26.23	25.60	25.46	27.18	25.49	25.47
K ₂ O	0.09	0.04	0.05	0.06	0.24	0.06	0.59	0.03	0.13	0.01	0.10
CaO	9.52	7.52	7.01	7.90	8.05	7.81	7.28	7.01	8.51	6.86	6.95
Na ₂ O	6.32	7.57	7.57	7.27	6.93	7.44	7.16	7.66	6.66	7.58	7.62
FeO	0.04	0.03	0.00	0.00	0.06	0.00	0.05	0.00	0.11	0.05	0.05
SrO	0.03	0.10	0.10	0.10	0.09	0.04	0.10	0.00	0.00	0.04	0.01
BaO	0.00	0.11	0.09	0.15	0.00	0.00	0.00	0.00	0.00	0.11	0.00
Total	99.45	99.13	98.67	99.50	99.68	99.89	99.67	99.34	99.32	98.89	98.95

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.53	2.63	2.65	2.60	2.60	2.61	2.64	2.65	2.56	2.65	2.65
Al	1.46	1.36	1.35	1.40	1.41	1.38	1.35	1.35	1.45	1.36	1.35
K	0.01	0.00	0.00	0.00	0.01	0.00	0.03	0.00	0.01	0.00	0.01
Ca	0.46	0.36	0.34	0.38	0.39	0.37	0.35	0.34	0.41	0.33	0.34
Na	0.55	0.66	0.66	0.64	0.60	0.65	0.62	0.67	0.58	0.66	0.67
Fe	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
%Ab	54.3	64.4	66.0	62.3	60.1	63.1	61.9	66.3	58.2	66.6	66.1
%An	45.2	35.4	33.7	37.4	38.5	36.6	34.8	33.5	41.1	33.3	33.3
%Or	0.5	0.2	0.3	0.4	1.4	0.3	3.4	0.2	0.7	0.1	0.6

BL1997-003a Plagioclase (continued)

Sample	P222	P223	P224	P225	P226	P227	P228	P229	P230	P231	P232
SiO ₂	59.01	67.55	55.99	57.95	56.06	46.23	58.75	57.12	59.83	57.98	58.98
Al ₂ O ₃	25.13	20.59	27.17	25.51	27.48	23.70	25.14	26.08	24.33	24.85	24.46
K ₂ O	0.07	0.01	0.07	0.44	0.05	0.43	0.05	0.05	0.09	0.06	0.06
CaO	6.91	6.34	9.17	7.36	9.53	5.94	6.81	8.14	6.28	6.95	6.52
Na ₂ O	7.68	5.53	6.47	7.07	6.26	4.74	7.70	7.02	8.21	7.66	8.01
FeO	0.10	0.00	0.00	0.04	0.07	6.61	0.05	0.05	0.02	0.05	0.00
SrO	0.00	0.06	0.00	0.05	0.01	0.00	0.00	0.00	0.00	0.01	0.12
BaO	0.06	0.17	0.00	0.32	0.02	0.11	0.13	0.13	0.00	0.00	0.11
Total	98.97	100.25	98.87	98.74	99.49	87.76	98.63	98.59	98.76	97.56	98.26

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.66	2.94	2.54	2.63	2.53	2.45	2.66	2.60	2.70	2.65	2.68
Al	1.34	1.06	1.45	1.37	1.46	1.48	1.34	1.40	1.29	1.34	1.31
K	0.00	0.00	0.00	0.03	0.00	0.03	0.00	0.00	0.01	0.00	0.00
Ca	0.33	0.30	0.45	0.36	0.46	0.34	0.33	0.40	0.30	0.34	0.32
Na	0.67	0.47	0.57	0.62	0.55	0.49	0.68	0.62	0.72	0.68	0.71
Fe	0.00	0.00	0.00	0.00	0.00	0.29	0.00	0.00	0.00	0.00	0.00
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Ab	66.5	61.1	55.8	61.9	54.1	57.1	67.0	60.7	69.9	66.4	68.7
% An	33.1	38.7	43.8	35.6	45.6	39.5	32.7	39.0	29.6	33.3	30.9
% Or	0.4	0.1	0.4	2.6	0.3	3.4	0.3	0.3	0.5	0.3	0.3

BLB97-003a Plagioclase (continued)

Sample	P233	P234	P235	P236	P237	P238	P239	P240
SiO ₂	57.13	57.10	59.12	57.87	57.27	58.52	55.38	53.01
Al ₂ O ₃	22.05	24.85	24.38	24.73	25.35	24.69	26.27	27.70
K ₂ O	0.12	0.36	0.06	0.04	0.08	0.09	0.02	0.09
CaO	7.28	6.71	6.02	6.66	7.41	6.43	8.34	10.18
Na ₂ O	8.56	7.40	8.28	7.95	7.28	7.90	6.74	5.69
FeO	0.09	0.06	0.06	0.00	0.07	0.01	0.05	0.02
SrO	0.04	0.00	0.01	0.11	0.00	0.04	0.12	0.02
BaO	0.00	0.00	0.02	0.00	0.00	0.00	0.09	0.02
Total	95.25	96.48	97.95	97.36	97.47	97.67	97.02	96.73

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8
Si	2.70	2.64	2.69	2.66	2.63	2.63	2.56	2.47
Al	1.23	1.36	1.31	1.34	1.37	1.37	1.43	1.52
K	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.01
Ca	0.37	0.33	0.29	0.33	0.36	0.36	0.41	0.51
Na	0.78	0.66	0.73	0.71	0.65	0.65	0.61	0.51
Fe	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
%Ab	67.6	65.2	71.1	68.2	63.7	63.7	59.3	50.0
%An	31.8	32.7	28.6	31.6	35.8	35.8	40.6	49.5
%Or	0.6	2.1	0.3	0.3	0.5	0.5	0.1	0.5

BLB97-003a Biotite

Sample	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12
SiO ₂	32.75	35.60	35.27	34.10	35.23	30.33	27.36	32.01	34.08	34.58	34.64
Al ₂ O ₃	14.58	16.25	16.11	16.19	16.22	16.74	17.04	16.67	16.72	16.11	16.48
TiO ₂	2.23	2.03	2.27	1.99	2.05	1.66	0.59	1.69	1.79	2.22	2.15
Cr ₂ O ₃	0.03	0.12	0.06	0.09	0.14	0.08	0.15	0.11	0.00	0.11	0.04
FeO	19.05	18.93	18.41	18.97	18.89	21.58	25.19	24.09	23.38	22.41	23.19
MnO	0.05	0.01	0.10	0.13	0.11	0.12	0.07	0.11	0.05	0.14	0.10
K ₂ O	7.34	8.30	8.30	7.99	8.32	4.29	0.97	5.60	7.43	8.57	8.61
MgO	10.93	11.79	11.38	10.99	11.37	11.73	13.62	9.77	9.50	8.68	8.84
CaO	0.23	0.09	0.17	0.19	0.12	0.29	0.15	0.16	0.14	0.05	0.07
Na ₂ O	0.12	0.04	0.13	0.06	0.08	0.10	0.00	0.02	0.04	0.10	0.06
Cl	0.21	0.20	0.20	0.18	0.20	0.08	0.02	0.20	0.21	0.19	0.25
BaO	0.24	0.22	0.65	0.27	0.31	0.36	0.04	0.24	0.22	0.18	0.53
Total	88.76	94.28	93.66	92.05	93.96	89.11	85.92	91.27	94.56	93.68	95.61

Number of cations in formula based on n oxygens

n	24	24	24	24	24	24	24	24	24	24	24
Si	5.95	6.01	6.02	5.94	6.00	5.53	5.12	5.70	5.87	5.99	5.93
Al iv	2.05	1.99	1.98	2.06	2.00	2.47	2.88	2.30	2.13	2.01	2.07
Al vi	1.07	1.25	1.26	1.27	1.26	1.12	0.89	1.19	1.27	1.27	1.26
Ti	0.30	0.26	0.29	0.26	0.26	0.23	0.08	0.23	0.23	0.29	0.28
Cr	0.00	0.02	0.01	0.01	0.02	0.01	0.02	0.02	0.00	0.02	0.01
Fe	2.89	2.67	2.63	2.76	2.69	3.29	3.94	3.58	3.37	3.24	3.32
Mn	0.01	0.00	0.01	0.02	0.02	0.02	0.01	0.02	0.01	0.02	0.01
K	1.70	1.79	1.81	1.78	1.81	1.00	0.23	1.27	1.63	1.89	1.88
Mg	2.96	2.97	2.89	2.86	2.89	3.19	3.80	2.59	2.44	2.24	2.26
Ca	0.04	0.02	0.03	0.03	0.02	0.06	0.03	0.03	0.03	0.01	0.01
Na	0.04	0.01	0.04	0.02	0.03	0.03	0.00	0.01	0.01	0.03	0.02
Cl	0.02	0.02	0.02	0.02	0.02	0.01	0.00	0.02	0.02	0.02	0.03
Ba	0.02	0.01	0.04	0.02	0.02	0.03	0.00	0.02	0.01	0.01	0.04
Fe/Fe+Mg	0.49	0.47	0.48	0.49	0.48	0.51	0.51	0.58	0.58	0.59	0.60

BLB97-003a Biotite (continued)

Sample	B13	B14	B15	B16	B18	B19	B20	B21	B22	B23	B24
SiO ₂	35.37	36.60	35.62	34.80	35.45	35.23	32.74	31.24	34.96	35.44	35.25
Al ₂ O ₃	17.04	16.93	15.09	15.68	15.79	15.90	16.61	16.70	15.62	15.84	16.14
TiO ₂	1.92	1.74	2.36	2.35	2.04	1.84	1.78	1.61	2.36	2.40	2.46
Cr ₂ O ₃	0.00	0.06	0.02	0.00	0.00	0.01	0.00	0.05	0.04	0.03	0.00
FeO	21.60	21.79	17.64	18.45	17.81	17.58	22.30	23.77	18.73	19.05	19.12
MnO	0.12	0.09	0.06	0.10	0.02	0.11	0.08	0.02	0.05	0.06	0.10
K ₂ O	8.45	8.69	8.08	8.47	8.18	8.43	6.05	4.66	8.58	7.87	9.06
MgO	9.22	8.69	11.64	11.36	11.73	11.93	11.02	11.09	10.96	11.75	11.31
CaO	0.19	0.69	0.19	0.10	0.03	0.10	0.09	0.10	0.07	0.08	0.16
Na ₂ O	0.00	0.00	0.03	0.03	0.00	0.00	0.02	0.03	0.14	0.08	0.02
Cl	0.26	0.23	0.16	0.20	0.16	0.20	0.19	0.12	0.18	0.18	0.15
BaO	0.35	0.53	0.16	0.31	0.47	0.49	0.48	0.46	0.00	0.22	0.00
Total	94.72	96.74	91.62	92.41	92.08	92.20	91.89	90.19	92.09	93.64	94.07

Number of cations in formula based on n oxygens

n	24	24	24	24	24	24	24	24	24	24	24
Si	6.00	6.12	6.14	6.01	6.09	6.06	5.75	5.59	6.04	6.02	5.97
Al iv	2.00	1.88	1.86	1.99	1.91	1.94	2.25	2.41	1.96	1.98	2.03
Al vi	1.41	1.46	1.21	1.20	1.29	1.28	1.18	1.11	1.22	1.19	1.19
Ti	0.25	0.22	0.31	0.31	0.26	0.24	0.23	0.22	0.31	0.31	0.31
Cr	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00
Fe	3.06	3.05	2.55	2.66	2.56	2.53	3.27	3.56	2.70	2.71	2.71
Mn	0.02	0.01	0.01	0.02	0.00	0.02	0.01	0.00	0.01	0.01	0.01
K	1.83	1.85	1.78	1.87	1.79	1.85	1.35	1.06	1.89	1.70	1.96
Mg	2.33	2.17	2.99	2.93	3.01	3.06	2.88	2.96	2.82	2.97	2.85
Ca	0.03	0.12	0.03	0.02	0.01	0.02	0.02	0.02	0.01	0.01	0.03
Na	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.05	0.03	0.01
Cl	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.02
Ba	0.02	0.03	0.01	0.02	0.03	0.03	0.03	0.03	0.00	0.01	0.00
Fe/Fe+Mg	0.57	0.58	0.46	0.48	0.46	0.45	0.53	0.55	0.49	0.48	0.49

BLB97-003a Biotite (continued)

Sample	B25
SiO ₂	35.67
Al ₂ O ₃	15.40
TiO ₂	2.31
CR ₂ O ₃	0.02
FeO	18.82
MnO	0.11
K ₂ O	8.89
MgO	11.18
CaO	0.10
Na ₂ O	0.00
Cl	0.19
BaO	0.35
Total	93.37

Number of cations in formula based on n oxygens

n 24

Si	6.09
Al iv	1.91
Al vi	1.20
Ti	0.30
Cr	0.00
Fe	2.69
Mn	0.02
K	1.94
Mg	2.85
Ca	0.02
Na	0.00
Cl	0.02
Ba	0.02
Fe/Fe+Mg	0.49

BLB97-003a Hornblende

Sample	H15	H16	H36	H37	H38	H39	I140	I141	I142	H176	H177
SiO ₂	44.42	44.85	40.10	41.77	45.24	40.75	41.14	40.62	40.52	40.82	41.28
Al ₂ O ₃	12.18	11.86	16.18	14.39	10.48	14.91	14.57	14.61	15.40	15.33	14.53
TiO ₂	0.57	0.65	0.46	0.05	0.01	0.05	0.05	0.35	0.39	0.18	0.33
Cr ₂ O ₃	0.00	0.00	0.11	0.00	0.00	0.02	0.00	0.00	0.02	0.00	0.01
FeO	17.58	16.37	21.15	19.66	18.56	21.76	21.51	20.40	20.01	21.50	21.61
MnO	0.15	0.24	0.20	0.22	0.28	0.27	0.24	0.21	0.33	0.23	0.24
K ₂ O	0.32	0.47	0.66	0.60	0.27	0.55	0.64	0.63	0.67	0.64	0.60
MgO	9.47	9.75	5.93	7.53	9.78	6.35	6.22	6.88	6.72	5.95	6.56
CaO	11.98	12.01	11.41	11.59	11.72	11.45	11.57	11.71	11.68	11.68	11.69
Na ₂ O	1.02	0.85	1.10	1.01	0.81	0.93	0.93	1.11	1.19	1.14	1.07
CL	0.00	0.00	0.27	0.22	0.09	0.19	0.14	0.23	0.23	0.24	0.21
F	0.06	0.02	0.07	0.06	0.05	0.05	0.02	0.04	0.03	0.00	0.00
Total	97.75	97.07	97.64	97.10	97.29	97.28	97.03	96.79	97.19	97.71	98.13

Number of cations in formula based on n oxygens

n	23	23	23	23	23	23	23	23	23	23	23
Si	6.63	6.70	6.14	6.37	6.80	6.27	6.33	6.26	6.21	6.25	6.29
Al ^{iv}	1.37	1.30	1.86	1.63	1.20	1.73	1.67	1.74	1.79	1.75	1.71
Al ^{vi}	0.77	0.78	1.06	0.96	0.66	0.97	0.98	0.91	0.99	1.02	0.90
Ti	0.06	0.07	0.05	0.01	0.00	0.01	0.01	0.04	0.04	0.02	0.04
Cr	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe	2.19	2.04	2.71	2.51	2.33	2.80	2.77	2.63	2.56	2.75	2.75
Mn	0.02	0.03	0.03	0.03	0.04	0.04	0.03	0.03	0.04	0.03	0.03
K	0.06	0.09	0.13	0.12	0.05	0.11	0.13	0.12	0.13	0.12	0.12
Mg	2.11	2.17	1.35	1.71	2.19	1.46	1.43	1.58	1.53	1.36	1.49
Ca	1.91	1.92	1.87	1.89	1.89	1.89	1.91	1.93	1.92	1.92	1.91
Na	0.29	0.25	0.33	0.30	0.24	0.28	0.28	0.33	0.35	0.34	0.32
Cl	0.00	0.00	0.03	0.02	0.01	0.02	0.01	0.02	0.02	0.02	0.02
F	0.03	0.01	0.03	0.03	0.02	0.02	0.01	0.02	0.01	0.00	0.00
Fe/Fe+Mg	0.51	0.48	0.67	0.59	0.52	0.66	0.66	0.62	0.63	0.67	0.65

BLB97-003a Hornblende (continued)

Sample	H78	H79	H107	H108	H109	H110	H136	H137	H138	H139	H140
SiO ₂	39.99	40.12	46.11	45.36	44.49	45.17	46.39	46.57	45.56	46.24	44.87
Al ₂ O ₃	15.67	16.32	12.10	12.13	13.22	12.50	9.77	10.47	10.35	9.24	11.10
TiO ₂	0.22	0.22	0.44	0.52	0.39	0.47	0.47	0.47	0.60	0.29	0.34
Cr ₂ O ₃	0.00	0.02	0.02	0.04	0.05	0.02	0.01	0.07	0.00	0.03	0.00
FeO	20.79	21.21	16.93	15.24	17.94	16.69	15.75	16.43	14.82	15.56	16.91
MnO	0.27	0.22	0.14	0.18	0.21	0.21	0.17	0.15	0.24	0.14	0.21
K ₂ O	0.78	0.80	0.56	0.43	0.45	0.46	0.35	0.31	0.33	0.25	0.25
MgO	6.00	5.65	9.84	10.65	9.33	9.76	11.28	10.34	11.44	11.74	10.20
CaO	11.82	11.68	11.64	11.87	11.73	11.83	11.88	11.88	11.77	11.99	11.81
Na ₂ O	1.07	1.10	1.00	1.01	1.09	0.97	0.70	0.90	0.82	0.78	0.85
Cl	0.22	0.28	0.13	0.11	0.13	0.14	0.11	0.08	0.09	0.09	0.11
F	0.00	0.00	0.03	0.05	0.00	0.01	0.06	0.04	0.00	0.00	0.02
Total	96.83	97.62	98.94	97.59	99.03	98.23	96.94	97.71	96.02	96.35	96.67

Number of cations in formula based on n oxygens

n	23	23	23	23	23	23	23	23	23	23	23
Si	6.18	6.15	6.75	6.70	6.56	6.67	6.90	6.89	6.82	6.92	6.74
Al iv	1.82	1.85	1.25	1.30	1.44	1.33	1.10	1.11	1.18	1.08	1.26
Al vi	1.03	1.10	0.84	0.81	0.85	0.84	0.61	0.71	0.65	0.55	0.71
Ti	0.03	0.03	0.05	0.06	0.04	0.05	0.05	0.05	0.07	0.03	0.04
Cr	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00
Fe	2.69	2.72	2.07	1.88	2.21	2.06	1.96	2.03	1.86	1.95	2.12
Mn	0.04	0.03	0.02	0.02	0.03	0.03	0.02	0.02	0.03	0.02	0.03
K	0.15	0.16	0.10	0.08	0.08	0.09	0.07	0.06	0.06	0.05	0.05
Mg	1.38	1.29	2.15	2.34	2.05	2.15	2.50	2.28	2.55	2.62	2.28
Ca	1.96	1.92	1.83	1.88	1.85	1.87	1.89	1.88	1.89	1.92	1.90
Na	0.32	0.33	0.28	0.29	0.31	0.28	0.20	0.26	0.24	0.23	0.25
Cl	0.02	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
F	0.00	0.00	0.01	0.02	0.00	0.00	0.03	0.02	0.00	0.00	0.01
Fe/Fe+Mg	0.66	0.68	0.49	0.45	0.52	0.49	0.44	0.47	0.42	0.43	0.48

BLB97-003a Hornblende (continued)

Sample	H141	H142	H143	H144	H145	H146	H147	H148	H170	H171	H172
SiO ₂	45.35	45.68	41.95	40.82	39.65	41.19	39.97	38.28	36.55	38.92	38.81
Al ₂ O ₃	11.18	10.23	14.26	14.13	16.72	14.71	16.46	17.70	20.81	14.23	14.50
TiO ₂	0.41	0.34	0.19	0.21	0.22	0.23	0.25	0.36	0.10	0.53	0.17
Cr ₂ O ₃	0.00	0.06	0.08	0.04	0.05	0.03	0.06	0.05	0.00	0.02	0.05
FeO	16.98	15.63	20.60	19.77	21.28	20.63	20.52	21.44	20.52	21.48	22.24
MnO	0.26	0.15	0.19	0.14	0.25	0.24	0.22	0.22	0.21	0.15	0.17
K ₂ O	0.30	0.31	0.58	0.52	0.64	0.62	0.82	0.89	0.68	0.75	0.74
MgO	9.72	11.16	6.57	6.78	5.28	6.19	6.32	4.97	4.13	5.86	5.56
CaO	12.18	11.76	11.72	11.59	11.57	11.61	11.59	11.45	11.57	11.49	11.63
Na ₂ O	0.90	0.77	0.95	0.90	0.97	1.03	0.99	0.93	0.99	0.93	0.88
CL	0.12	0.11	0.18	0.23	0.27	0.23	0.23	0.32	0.18	0.24	0.25
F	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.19
Total	97.40	96.20	97.28	95.13	96.90	96.71	97.43	96.61	95.80	94.60	95.19

Number of cations in formula based on n oxygens

n	23	23	23	23	23	23	23	23	23	23	23
Si	6.77	6.85	6.41	6.36	6.12	6.34	6.12	5.95	5.70	6.20	6.18
Al iv	1.23	1.15	1.59	1.64	1.88	1.66	1.88	2.05	2.30	1.80	1.82
Al vi	0.73	0.65	0.97	0.96	1.16	1.01	1.09	1.20	1.53	0.87	0.90
Ti	0.05	0.04	0.02	0.02	0.03	0.03	0.03	0.04	0.01	0.06	0.02
Cr	0.00	0.01	0.01	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.01
Fe	2.12	1.96	2.63	2.58	2.75	2.66	2.63	2.79	2.68	2.86	2.96
Mn	0.03	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.02	0.02
K	0.06	0.06	0.11	0.10	0.13	0.12	0.16	0.18	0.14	0.15	0.15
Mg	2.16	2.49	1.50	1.58	1.21	1.42	1.44	1.15	0.96	1.39	1.32
Ca	1.95	1.89	1.92	1.94	1.91	1.91	1.90	1.91	1.93	1.96	1.98
Na	0.26	0.22	0.28	0.27	0.29	0.31	0.29	0.28	0.30	0.29	0.27
Cl	0.01	0.01	0.02	0.02	0.03	0.02	0.02	0.03	0.02	0.02	0.03
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.09
Fe/Fe+Mg	0.49	0.44	0.64	0.62	0.69	0.65	0.65	0.71	0.74	0.67	0.69

BLB97-003a Hornblende (continued)

Sample	H173	H174	H175	H176	H177	H178	H179
SiO ₂	38.03	43.49	45.39	45.10	45.70	39.64	38.71
Al ₂ O ₃	15.31	11.08	8.90	9.08	9.00	16.17	16.04
TiO ₂	0.31	0.45	0.50	0.46	0.45	0.24	0.31
Cr ₂ O ₃	0.00	0.05	0.07	0.02	0.00	0.00	0.00
FeO	21.70	17.14	15.93	15.69	15.14	21.18	21.26
MnO	0.34	0.14	0.13	0.14	0.20	0.29	0.19
K ₂ O	0.65	0.36	0.28	0.33	0.30	0.62	0.64
MgO	5.12	9.59	10.97	11.10	11.47	5.21	5.17
CaO	11.20	11.53	12.12	12.11	12.05	11.60	11.41
Na ₂ O	0.98	0.79	0.69	0.72	0.70	0.91	0.96
CL	0.28	0.15	0.06	0.08	0.07	0.16	0.16
F	0.08	0.31	0.29	0.20	0.14	0.10	0.27
Total	94.00	95.09	95.34	95.03	95.23	96.12	95.12

Number of cations in formula based on n oxygens

n	23	23	23	23	23	23	23
Si	6.11	6.69	6.91	6.88	6.93	6.17	6.12
Al iv	1.89	1.31	1.09	1.12	1.07	1.83	1.88
Al vi	1.01	0.70	0.51	0.52	0.53	1.14	1.10
Ti	0.04	0.05	0.06	0.05	0.05	0.03	0.04
Cr	0.00	0.01	0.01	0.00	0.00	0.00	0.00
Fe	2.91	2.21	2.03	2.00	1.92	2.76	2.81
Mn	0.05	0.02	0.02	0.02	0.03	0.04	0.03
K	0.13	0.07	0.05	0.07	0.06	0.12	0.13
Mg	1.23	2.20	2.49	2.53	2.59	1.21	1.22
Ca	1.93	1.90	1.98	1.98	1.96	1.93	1.93
Na	0.30	0.24	0.20	0.21	0.20	0.27	0.29
Cl	0.03	0.01	0.01	0.01	0.01	0.02	0.02
F	0.04	0.15	0.14	0.10	0.07	0.05	0.13
Fe/Fe+Mg	0.70	0.50	0.45	0.44	0.43	0.70	0.70

BLB97-003a Garnet

Sample	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11
SiO ₂	37.33	37.82	37.60	37.56	38.22	37.72	38.13	38.14	38.16	37.27	37.67
Al ₂ O ₃	20.56	21.06	20.74	21.39	21.35	21.35	21.28	21.39	21.49	21.01	21.10
TiO ₂	0.05	0.10	0.08	0.06	0.14	0.12	0.09	0.06	0.18	0.68	0.20
Cr ₂ O ₃	0.04	0.04	0.06	0.03	0.10	0.02	0.07	0.07	0.07	0.06	0.06
FeO	26.84	27.24	26.83	28.38	28.48	29.35	29.65	29.29	28.58	28.74	28.24
MnO	0.82	0.61	0.73	0.77	0.89	1.24	1.78	1.47	1.88	2.73	2.83
MgO	3.37	3.42	2.97	2.97	2.76	2.88	2.77	3.16	3.12	2.25	2.31
CaO	8.88	9.40	9.48	9.11	9.19	8.03	7.78	7.71	8.21	7.85	8.25
Na ₂ O	-	-	-	-	-	-	-	-	-	-	-
K ₂ O	-	-	-	-	-	-	-	-	-	-	-
Total	98.52	99.69	98.49	100.27	101.13	100.71	101.55	101.29	101.69	100.59	100.66

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	3.01	3.00	3.01	2.97	3.00	2.98	2.99	2.99	2.98	2.96	2.99
Al iv	-0.01	0.00	-0.01	0.03	0.00	0.02	0.01	0.01	0.02	0.04	0.01
Al vi	1.96	1.96	1.97	1.97	1.97	1.97	1.96	1.97	1.96	1.93	1.96
Ti	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.00	0.01	0.04	0.01
Cr	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Fe	1.81	1.80	1.80	1.88	1.87	1.94	1.95	1.92	1.87	1.91	1.87
Mn	0.06	0.04	0.05	0.05	0.06	0.08	0.12	0.10	0.12	0.18	0.19
Mg	0.41	0.40	0.35	0.35	0.32	0.34	0.32	0.37	0.36	0.27	0.27
Ca	0.77	0.80	0.81	0.77	0.77	0.68	0.65	0.65	0.69	0.67	0.70
Na	-	-	-	-	-	-	-	-	-	-	-
K	-	-	-	-	-	-	-	-	-	-	-
% Alm	59.6	59.2	59.6	61.5	61.8	63.8	64.0	63.3	61.4	63.1	61.7
% Sp	1.9	1.4	1.7	1.7	2.0	2.8	4.0	3.3	4.3	6.5	6.7
% Py	15.4	15.3	13.3	13.0	12.0	12.6	11.9	13.9	13.6	9.7	9.9
% Cr	33.8	35.5	37.0	33.9	34.3	28.8	27.4	27.1	29.2	28.3	30.0

BLB97-003a Garnet (continued)

Sample	G12	G13	G14	G30	G31	G32	G33	G34	G35	G43	G44
SiO ₂	37.72	38.28	38.27	38.27	37.61	38.52	38.44	38.53	38.31	37.74	37.42
Al ₂ O ₃	21.24	21.25	21.08	21.59	21.25	21.67	21.75	21.53	21.69	21.59	21.66
TiO ₂	0.16	0.09	0.12	0.03	0.05	0.08	0.06	0.05	0.04	0.12	0.08
Cr ₂ O ₃	0.01	0.04	0.06	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00
FeO	27.92	28.96	27.42	27.89	27.75	27.36	27.38	27.80	27.22	27.64	26.73
MnO	1.87	1.95	0.91	0.76	2.40	0.65	0.49	0.78	0.67	0.99	0.80
MgO	3.17	2.90	2.99	3.00	1.83	3.55	3.58	3.26	3.22	2.73	2.87
CaO	8.31	8.31	9.87	9.14	9.04	9.37	9.32	9.43	9.36	9.94	10.07
Na ₂ O	-	-	-	-	-	-	-	-	-	-	-
K ₂ O	-	-	-	-	-	-	-	-	-	-	-
Total	100.40	101.78	100.72	100.68	99.96	101.20	101.02	101.38	100.51	100.75	99.63

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	2.98	2.99	3.01	3.00	3.00	3.00	2.99	3.00	3.00	2.97	2.97
Al iv	0.02	0.01	-0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.03	0.03
Al vi	1.96	1.95	1.96	2.00	1.99	1.98	1.99	1.98	2.00	1.97	1.99
Ti	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe	1.85	1.89	1.80	1.83	1.85	1.78	1.78	1.81	1.78	1.82	1.77
Mn	0.13	0.13	0.06	0.05	0.16	0.04	0.03	0.05	0.04	0.07	0.05
Mg	0.37	0.34	0.35	0.35	0.22	0.41	0.42	0.38	0.38	0.32	0.34
Ca	0.70	0.70	0.83	0.77	0.77	0.78	0.78	0.79	0.79	0.84	0.86
Na	-	-	-	-	-	-	-	-	-	-	0.00
K	-	-	-	-	-	-	-	-	-	-	0.00
% Alm	60.5	61.9	59.2	61.0	61.6	59.0	59.3	59.8	59.7	59.8	58.7
% Sp	4.3	4.4	2.0	1.7	5.7	1.4	1.1	1.7	1.5	2.2	1.8
% Py	14.0	12.4	13.0	13.2	7.8	15.8	16.0	14.3	14.4	11.8	12.7
% Gr	30.0	29.5	37.6	34.4	34.6	35.0	34.9	35.1	35.6	38.0	39.5

BLB97-003a Garnet (continued)

Sample	G45	G46	G47	G48	G49	G50	G51	G68	G69	G70	G71
SiO ₂	37.91	37.91	37.25	37.77	37.99	37.90	37.70	37.39	37.30	37.60	38.03
Al ₂ O ₃	21.99	22.03	21.80	21.92	22.04	22.08	22.14	21.40	21.61	21.86	21.63
TiO ₂	0.10	0.13	0.15	0.08	0.08	0.08	0.08	0.28	0.10	0.12	0.03
Cr ₂ O ₃	0.01	0.00	0.00	0.02	0.00	0.00	0.00	0.14	0.00	0.00	0.00
FeO	27.05	28.64	28.72	29.17	27.64	27.40	27.86	28.98	29.97	29.60	28.69
MnO	0.75	1.73	1.54	1.28	0.81	0.83	0.87	2.29	0.99	1.11	3.23
MgO	2.83	2.31	2.61	2.77	2.94	2.90	3.16	2.62	2.84	2.74	1.75
CaO	10.19	8.52	8.44	8.34	10.02	9.92	9.64	7.73	7.93	8.02	7.75
Na ₂ O	-	-	-	-	-	-	-	-	-	-	-
K ₂ O	-	-	-	-	-	-	-	-	-	-	-
Total	100.83	101.27	100.51	101.35	101.52	101.11	101.45	100.83	100.74	101.05	101.11

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	2.97	2.97	2.95	2.96	2.96	2.96	2.94	2.96	2.95	2.96	3.00
Al iv	0.03	0.03	0.05	0.04	0.04	0.04	0.06	0.04	0.05	0.04	0.00
Al vi	2.00	2.01	1.98	1.99	1.98	2.00	1.98	1.96	1.97	1.99	2.02
Ti	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.02	0.01	0.01	0.00
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Fe	1.77	1.88	1.90	1.91	1.80	1.79	1.82	1.92	1.98	1.95	1.89
Mn	0.05	0.11	0.10	0.09	0.05	0.05	0.06	0.15	0.07	0.07	0.22
Mg	0.33	0.27	0.31	0.32	0.34	0.34	0.37	0.31	0.34	0.32	0.21
Ca	0.85	0.72	0.72	0.70	0.84	0.83	0.81	0.66	0.67	0.68	0.66
Na	-	-	-	-	-	-	-	-	-	-	-
K	-	-	-	-	-	-	-	-	-	-	-
% Alm	58.9	63.0	62.8	63.3	59.4	59.4	59.6	63.2	64.9	64.5	63.7
% Sp	1.7	4.0	3.5	2.9	1.8	1.9	1.9	5.3	2.2	2.5	7.8
% Py	12.3	10.0	11.3	12.0	12.7	12.6	13.7	11.3	12.3	11.9	7.4
% Cr	39.7	31.6	31.0	30.2	38.1	38.0	35.9	27.5	28.2	28.9	28.3

BLB97-003a Garnet (continued)

Sample	G72	G73	G74	G75	G80	G81	G82	G83	G84	G85	G86
SiO ₂	38.04	37.63	36.45	37.95	38.63	38.30	38.10	37.57	37.87	37.78	37.71
Al ₂ O ₃	21.80	21.69	21.32	21.81	22.36	22.04	22.18	22.11	21.93	21.92	22.05
TiO ₂	0.04	0.12	0.02	0.03	0.06	0.03	0.00	0.07	0.07	0.10	0.04
Cr ₂ O ₃	0.00	0.00	0.00	0.04	0.02	0.01	0.00	0.00	0.00	0.00	0.01
FeO	29.52	28.72	28.07	29.07	27.36	27.26	27.39	28.40	28.96	28.65	29.50
MnO	1.41	1.47	0.96	1.17	0.70	0.82	0.89	0.85	0.88	0.94	1.04
MgO	2.92	2.91	2.86	3.11	3.58	3.49	3.54	2.75	2.80	2.77	2.77
CaO	7.77	8.14	7.81	7.49	9.31	9.44	9.49	9.30	8.89	9.10	8.16
Na ₂ O	-	-	-	-	-	-	-	-	-	-	-
K ₂ O	-	-	-	-	-	-	-	-	-	-	-
Total	101.5	100.68	97.49	100.67	102.02	101.39	101.59	101.05	101.40	101.26	101.28

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	2.98	2.97	2.96	2.99	2.98	2.98	2.96	2.95	2.96	2.96	2.96
Al iv	0.02	0.03	0.04	0.01	0.02	0.02	0.04	0.05	0.04	0.04	0.04
Al vi	1.99	1.99	2.01	2.01	1.99	1.99	1.99	1.99	1.99	1.99	2.00
Ti	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe	1.93	1.89	1.91	1.91	1.76	1.77	1.78	1.86	1.90	1.88	1.94
Mn	0.09	0.10	0.07	0.08	0.05	0.05	0.06	0.06	0.06	0.06	0.07
Mg	0.34	0.34	0.35	0.36	0.41	0.40	0.41	0.32	0.33	0.32	0.32
Ca	0.65	0.69	0.68	0.63	0.77	0.79	0.79	0.78	0.75	0.76	0.69
Na	-	-	-	-	-	-	-	-	-	-	-
K	-	-	-	-	-	-	-	-	-	-	-
% Alm	64.0	62.7	63.6	64.0	59.0	58.7	58.6	61.6	62.6	62.0	64.2
% Sp	3.2	3.4	2.3	2.7	1.6	1.8	2.0	1.9	2.0	2.1	2.3
% Py	12.7	12.8	13.1	13.9	16.0	15.5	15.6	11.9	12.1	12.0	12.0
% Gr	27.5	29.5	29.3	26.8	34.6	35.2	35.1	34.9	32.7	33.8	29.5

BLB97-003a Garnet (continued)

Sample	G87	G88	G89	G90	G91	G92	G93	G94	G111	G112	G113
SiO ₂	37.88	37.72	37.83	38.15	38.18	38.04	38.42	37.62	38.32	38.26	38.07
Al ₂ O ₃	22.02	22.03	21.73	21.87	21.79	22.01	22.14	21.95	22.00	22.17	22.08
TiO ₂	0.13	0.09	0.12	0.12	0.10	0.05	0.04	0.05	0.07	0.08	0.10
Cr ₂ O ₃	0.01	0.04	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
FeO	30.12	29.87	29.89	29.22	29.49	28.15	27.41	27.87	27.21	27.52	27.45
MnO	1.04	1.05	1.02	1.01	0.96	0.76	0.68	1.16	0.73	0.74	0.66
MgO	2.68	2.66	2.62	2.87	2.58	3.55	3.54	2.84	3.63	3.62	3.68
CaO	7.82	8.36	8.48	8.45	8.72	9.25	9.23	8.94	9.27	9.26	9.13
Na ₂ O	-	-	-	-	-	-	-	-	-	-	-
K ₂ O	-	-	-	-	-	-	-	-	-	-	-
Total	101.70	101.82	101.70	101.69	101.83	101.81	101.46	100.43	101.23	101.65	101.17

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	2.96	2.95	2.96	2.98	2.98	2.96	2.98	2.97	2.98	2.97	2.96
Al iv	0.04	0.05	0.04	0.02	0.02	0.04	0.02	0.03	0.02	0.03	0.04
Al vi	2.00	1.98	1.97	1.99	1.99	1.97	2.00	2.01	1.99	1.99	1.99
Ti	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe	1.97	1.95	1.96	1.91	1.93	1.83	1.78	1.84	1.77	1.78	1.79
Mn	0.07	0.07	0.07	0.07	0.06	0.05	0.04	0.08	0.05	0.05	0.04
Mg	0.31	0.31	0.31	0.33	0.30	0.41	0.41	0.33	0.42	0.42	0.43
Ca	0.66	0.70	0.71	0.71	0.73	0.77	0.77	0.76	0.77	0.77	0.76
Na	-	-	-	-	-	-	-	-	-	-	-
K	-	-	-	-	-	-	-	-	-	-	-
% Alm	65.5	64.4	64.3	63.3	63.8	59.8	59.3	61.2	58.8	59.1	59.2
% Sp	2.3	2.3	2.3	2.3	2.1	1.7	1.5	2.6	1.6	1.6	1.5
% Py	11.6	11.4	11.2	12.5	11.0	15.5	15.8	12.5	16.3	16.1	16.5
% Gr	27.9	30.0	30.5	30.6	31.9	33.6	34.4	33.6	34.5	34.2	33.7

BLB97-003a Garnet (continued)

Sample	G114	G115	G116	G117	G118	G119	G120	G121	G122	G123	G149
SiO ₂	38.05	38.26	37.77	37.44	37.79	37.54	37.66	38.31	38.48	38.75	38.55
Al ₂ O ₃	22.24	21.70	21.76	22.00	21.81	21.55	21.67	22.22	22.13	22.07	21.18
TiO ₂	0.08	0.07	0.13	0.09	0.09	0.14	0.17	0.08	0.07	0.06	0.00
Cr ₂ O ₃	0.00	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.03
FeO	28.49	29.47	30.36	30.33	30.50	29.59	30.00	27.78	27.20	27.26	26.89
MnO	0.89	1.15	1.16	1.32	1.42	1.23	1.30	0.85	0.72	0.70	1.02
MgO	2.74	2.48	2.61	2.68	2.35	2.35	2.32	3.44	3.58	3.46	3.12
CaO	9.33	8.28	7.92	7.59	7.40	7.73	8.79	9.27	9.28	9.13	9.07
Na ₂ O	-	-	-	-	-	-	-	-	-	-	-
K ₂ O	-	-	-	-	-	-	-	-	-	-	-
Total	101.82	101.41	101.73	101.45	101.37	100.13	101.91	101.95	101.47	101.43	99.86

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	2.96	3.00	2.96	2.95	2.98	2.98	2.95	2.97	2.98	3.00	3.04
Al iv	0.04	0.00	0.04	0.05	0.02	0.02	0.05	0.03	0.02	0.00	-0.04
Al vi	2.00	2.00	1.97	1.99	2.00	2.00	1.96	1.99	2.00	2.02	2.00
Ti	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe	1.85	1.93	1.99	2.00	2.01	1.97	1.97	1.80	1.76	1.77	1.77
Mn	0.06	0.08	0.08	0.09	0.09	0.08	0.09	0.06	0.05	0.05	0.07
Mg	0.32	0.29	0.31	0.31	0.28	0.28	0.27	0.40	0.41	0.40	0.37
Ca	0.78	0.69	0.67	0.64	0.62	0.66	0.74	0.77	0.77	0.76	0.77
Na	-	-	-	-	-	-	-	-	-	-	-
K	-	-	-	-	-	-	-	-	-	-	-
% Alm	61.6	64.5	65.5	65.7	66.9	65.9	64.2	59.5	58.9	59.5	59.6
% Sp	2.0	2.6	2.6	3.0	3.3	2.9	2.9	1.9	1.6	1.6	2.3
% Py	11.8	10.7	11.2	11.5	10.1	10.3	9.7	15.1	16.0	15.6	14.1
% Gr	34.9	30.3	28.0	26.7	26.2	28.3	31.8	34.2	34.7	34.3	34.7

BLB97-003a Garnet (continued)

Sample	G150	G151	G152	G153	G154	G155	G156	G157	G158	G159	G160
SiO ₂	37.19	37.21	38.37	37.36	36.96	37.58	37.36	37.52	36.89	36.80	36.84
Al ₂ O ₃	21.76	21.65	21.29	21.33	21.55	21.45	21.68	21.75	21.20	21.18	21.00
TiO ₂	0.02	0.03	0.08	0.01	0.02	0.07	0.08	0.05	0.13	0.10	0.04
Cr ₂ O ₃	0.00	0.00	0.00	0.01	0.00	0.03	0.02	0.00	0.00	0.02	0.00
FeO	26.69	27.09	27.65	27.26	27.36	26.51	26.55	27.08	27.94	27.28	27.42
MnO	1.22	0.79	0.86	0.99	0.96	0.77	0.76	0.89	0.76	0.88	0.79
MgO	2.92	2.94	2.80	2.92	2.83	3.07	2.96	3.11	2.86	3.02	3.04
CaO	9.06	9.13	9.40	9.23	9.25	9.46	9.43	9.43	9.29	9.29	9.29
Na ₂ O	-	-	-	-	-	-	-	-	0.00	0.00	0.00
K ₂ O	-	-	-	-	-	-	-	-	0.00	0.00	0.00
Total	98.86	98.84	100.45	99.11	98.93	98.94	98.84	99.83	99.08	98.57	98.43

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	2.97	2.97	3.02	2.98	2.96	2.99	2.98	2.97	2.96	2.96	2.97
Al iv	0.03	0.03	-0.02	0.02	0.04	0.01	0.02	0.03	0.04	0.04	0.03
Al vi	2.02	2.01	1.99	1.99	1.99	2.00	2.01	2.00	1.96	1.97	1.96
Ti	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe	1.78	1.81	1.82	1.82	1.83	1.76	1.77	1.79	1.87	1.83	1.85
Mn	0.08	0.05	0.06	0.07	0.07	0.05	0.05	0.06	0.05	0.06	0.05
Mg	0.35	0.35	0.33	0.35	0.34	0.36	0.35	0.37	0.34	0.36	0.37
Ca	0.78	0.78	0.79	0.79	0.79	0.81	0.81	0.80	0.80	0.80	0.80
Na	-	-	-	-	-	-	-	-	-	0.00	0.00
K	-	-	-	-	-	-	-	-	-	0.00	0.00
% Alm	59.7	60.4	60.7	60.2	60.5	59.1	59.4	59.4	61.1	60.0	60.2
% Sp	2.8	1.8	1.9	2.3	2.2	1.8	1.8	2.0	1.7	2.0	1.8
% Py	13.2	13.2	12.3	13.0	12.6	13.9	13.4	13.8	12.5	13.4	13.5
% Gr	35.0	35.3	35.9	35.3	35.5	37.0	37.1	36.0	35.2	35.5	35.4

BLB97-003a Gamet (continued)

Sample	G161	G162	G163	G164	G165	G166	G167	G168	G169	G170	G171
SiO ₂	36.60	36.77	36.74	36.80	36.88	36.96	37.37	37.10	37.31	36.95	36.92
Al ₂ O ₃	21.24	21.00	21.00	21.35	21.12	21.33	21.25	21.24	21.36	21.15	21.21
TiO ₂	0.14	0.14	0.12	0.08	0.11	0.05	0.07	0.15	0.10	0.12	0.08
Cr ₂ O ₃	0.00	0.02	0.01	0.02	0.05	0.03	0.00	0.00	0.02	0.00	0.03
FeO	29.01	28.61	28.79	28.00	28.23	27.38	26.75	27.30	27.25	28.13	29.26
MnO	0.83	0.86	0.86	0.77	0.94	0.73	0.69	0.90	1.06	1.18	1.33
MgO	2.68	2.61	2.68	2.94	2.95	3.25	3.31	3.13	2.79	2.59	2.70
CaO	8.62	8.71	8.88	9.11	8.98	9.31	9.54	9.52	9.63	8.89	7.99
Na ₂ O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K ₂ O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Total	99.12	98.72	99.08	99.07	99.26	99.05	98.97	99.35	99.53	99.01	99.54

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	2.94	2.97	2.96	2.95	2.96	2.96	2.98	2.96	2.97	2.97	2.96
Al iv	0.06	0.03	0.04	0.05	0.04	0.04	0.02	0.04	0.03	0.03	0.04
Al vi	1.96	1.96	1.95	1.97	1.95	1.97	1.98	1.96	1.97	1.97	1.96
Ti	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.00
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe	1.95	1.93	1.94	1.88	1.89	1.83	1.78	1.82	1.81	1.89	1.96
Mn	0.06	0.06	0.06	0.05	0.06	0.05	0.05	0.06	0.07	0.08	0.09
Mg	0.32	0.31	0.32	0.35	0.35	0.39	0.39	0.37	0.33	0.31	0.32
Ca	0.74	0.75	0.77	0.78	0.77	0.80	0.82	0.81	0.82	0.77	0.69
Na	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Alm	63.5	63.2	62.9	61.3	61.4	59.7	58.7	59.4	59.7	62.0	64.1
% Sp	1.9	2.0	1.9	1.7	2.1	1.6	1.6	2.0	2.4	2.7	3.0
% Py	11.7	11.5	11.6	13.0	12.9	14.5	14.9	13.8	12.2	11.4	11.8
% Gr	31.9	32.7	33.0	34.3	33.4	35.2	36.7	36.1	37.1	33.6	28.9

BLB97-003a Garnet (continued)

Sample	G172	G173	G174	G175	G176	G177	G178	G179	G180	G181	G182
SiO ₂	36.78	36.89	36.72	36.70	36.68	36.89	36.79	36.64	36.81	37.01	36.77
Al ₂ O ₃	21.11	21.41	21.02	21.07	21.08	21.32	21.08	21.14	21.18	21.06	21.25
TiO ₂	0.09	0.17	0.13	0.11	0.09	0.14	0.09	0.17	0.12	0.07	0.05
Cr ₂ O ₃	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.01
FeO	28.85	28.21	28.50	28.37	28.63	28.03	28.27	28.48	28.54	27.76	27.61
MnO	1.23	1.31	1.32	1.43	1.46	1.30	1.41	1.33	1.32	1.30	1.14
MgO	2.69	2.61	2.59	2.55	2.58	2.56	2.54	2.60	2.52	2.75	2.88
CaO	8.59	8.70	8.39	8.48	8.31	8.88	8.77	8.54	8.68	9.21	9.06
Na ₂ O	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.01	0.00	0.00
K ₂ O	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.02	0.00	0.01
Total	99.36	99.31	98.67	98.73	98.82	99.13	98.94	98.89	99.23	99.17	98.79

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	2.95	2.95	2.97	2.96	2.96	2.96	2.96	2.95	2.96	2.97	2.96
Al iv	0.05	0.05	0.03	0.04	0.04	0.04	0.04	0.05	0.04	0.03	0.04
Al vi	1.95	1.98	1.97	1.97	1.97	1.98	1.96	1.96	1.96	1.96	1.97
Ti	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe	1.94	1.89	1.92	1.92	1.93	1.88	1.90	1.92	1.92	1.86	1.86
Mn	0.08	0.09	0.09	0.10	0.10	0.09	0.10	0.09	0.09	0.09	0.08
Mg	0.32	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.30	0.33	0.35
Ca	0.74	0.75	0.73	0.73	0.72	0.76	0.76	0.74	0.75	0.79	0.78
Na	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Alm	62.9	62.2	63.0	62.7	63.1	61.9	62.2	62.7	62.7	60.7	60.6
% Sp	2.8	3.0	3.1	3.3	3.4	3.0	3.2	3.1	3.0	3.0	2.6
% Py	11.6	11.4	11.4	11.2	11.3	11.2	11.1	11.4	11.0	12.0	12.7
% Gr	31.6	32.6	31.2	31.6	30.7	33.6	32.8	31.7	32.4	34.7	34.2

BLB97-003a Garnet (continued)

Sample	G183	G184	G185	G186	G187	G188	G189	G190	G191	G192	G193
SiO ₂	36.94	37.18	37.50	37.10	37.18	37.30	37.01	36.98	37.15	37.58	37.34
Al ₂ O ₃	21.35	21.41	21.30	21.47	21.31	21.40	21.37	21.39	22.12	21.67	21.78
TiO ₂	0.12	0.11	0.10	0.07	0.06	0.08	0.09	0.10	0.06	0.08	0.10
Cr ₂ O ₃	0.02	0.00	0.03	0.00	0.03	0.04	0.04	0.04	0.03	0.00	0.02
FeO	27.18	27.22	26.52	26.82	26.77	26.97	27.05	27.31	27.36	27.26	26.96
MnO	0.98	0.87	0.85	0.78	0.64	0.83	0.88	0.88	1.03	1.15	1.02
MgO	3.18	3.18	3.38	3.54	3.64	3.26	3.19	3.02	2.86	2.81	2.88
CaO	9.60	9.40	9.49	9.45	9.23	9.41	9.54	9.47	9.64	9.56	9.72
Na ₂ O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
K ₂ O	0.00	0.01	0.01	0.02	0.00	0.00	0.00	0.00	0.03	0.02	0.00
Total	99.38	99.38	99.18	99.26	98.85	99.30	99.18	99.19	100.29	100.15	99.81

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	2.95	2.96	2.98	2.95	2.97	2.97	2.95	2.95	2.93	2.97	2.96
Al iv	0.05	0.04	0.02	0.05	0.03	0.03	0.05	0.05	0.07	0.03	0.04
Al vi	1.95	1.97	1.98	1.97	1.97	1.97	1.97	1.97	1.99	1.99	1.99
Ti	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.01
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe	1.81	1.81	1.76	1.79	1.79	1.79	1.81	1.82	1.81	1.80	1.79
Mn	0.07	0.06	0.06	0.05	0.04	0.06	0.06	0.06	0.07	0.08	0.07
Mg	0.38	0.38	0.40	0.42	0.43	0.39	0.38	0.36	0.34	0.33	0.34
Ca	0.82	0.80	0.81	0.81	0.79	0.80	0.82	0.81	0.82	0.81	0.83
Na	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Alm	58.9	59.4	58.2	58.3	58.6	59.0	59.0	59.7	59.7	59.7	59.1
% Sp	2.2	2.0	1.9	1.7	1.4	1.9	2.0	2.0	2.3	2.6	2.3
% Py	14.0	14.1	15.2	15.9	16.5	14.6	14.2	13.4	12.5	12.3	12.7
% Gr	36.3	35.6	36.4	35.7	34.9	35.9	36.3	36.1	36.9	36.6	37.6

BLB97-003a Garnet (continued)

Sample	G194	G195	G196	G197	G198	G199	G200	G201	G202	G203	G204
SiO ₂	37.72	36.77	37.11	36.93	36.53	36.78	36.58	36.67	36.84	37.32	37.69
Al ₂ O ₃	21.87	21.46	21.61	21.59	21.26	21.38	21.29	21.39	21.15	21.50	21.58
TiO ₂	0.04	0.10	0.14	0.07	0.11	0.15	0.12	0.14	0.13	0.15	0.15
Cr ₂ O ₃	0.04	0.00	0.04	0.08	0.08	0.03	0.09	0.00	0.01	0.05	0.02
FeO	27.32	27.89	28.05	28.15	27.54	28.42	28.45	28.23	28.63	27.67	28.29
MnO	0.95	0.98	1.12	1.06	1.18	1.19	1.10	1.19	1.22	1.21	1.23
MgO	2.72	2.66	2.75	2.60	2.66	2.55	2.66	2.61	2.57	2.50	2.50
CaO	9.94	9.03	8.78	8.96	9.04	8.70	8.79	8.79	8.57	8.73	9.02
Na ₂ O	0.00	0.00	0.00	0.00	0.00	0.03	0.02	0.00	0.00	0.01	0.00
K ₂ O	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.00
Total	100.60	98.89	99.59	99.46	98.41	99.23	99.09	99.02	99.14	99.14	100.47

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	2.97	2.95	2.96	2.95	2.95	2.95	2.94	2.95	2.96	2.98	2.98
Al iv	0.03	0.05	0.04	0.05	0.05	0.05	0.06	0.05	0.04	0.02	0.02
Al vi	1.99	1.98	1.99	1.98	1.97	1.97	1.96	1.97	1.97	2.01	1.99
Ti	0.00	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Fe	1.80	1.87	1.87	1.88	1.86	1.91	1.91	1.90	1.92	1.85	1.87
Mn	0.06	0.07	0.08	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Mg	0.32	0.32	0.33	0.31	0.32	0.31	0.32	0.31	0.31	0.30	0.29
Ca	0.84	0.78	0.75	0.77	0.78	0.75	0.76	0.76	0.74	0.75	0.76
Na	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Alm	59.5	61.7	61.9	62.1	61.1	62.7	62.4	62.2	63.0	62.1	62.1
% Sp	2.2	2.2	2.6	2.4	2.7	2.7	2.5	2.7	2.8	2.8	2.8
% Py	11.8	11.7	12.1	11.4	11.8	11.2	11.6	11.4	11.2	11.1	10.8
% Gr	38.4	34.4	33.0	33.9	34.6	32.6	32.8	33.0	31.9	33.6	34.0

BLB97-003a Garnet (continued)

Sample	G205	G206	G207	G208	G209	G210	G211	G212	G213	G214	G215
SiO ₂	37.20	37.22	37.04	36.93	36.81	36.99	37.43	37.78	37.32	36.73	37.87
Al ₂ O ₃	21.63	21.29	21.38	21.32	21.33	21.12	21.58	21.89	21.71	21.39	21.82
TiO ₂	0.16	0.06	0.16	0.16	0.08	0.15	0.15	0.12	0.20	0.07	0.03
Cr ₂ O ₃	0.00	0.07	0.02	0.03	0.00	0.02	0.04	0.00	0.02	0.04	0.08
FeO	28.46	28.10	28.13	28.17	28.45	29.07	28.25	28.60	28.69	27.92	29.04
MnO	1.30	1.13	1.12	1.21	1.80	1.83	1.98	1.78	2.31	1.94	1.80
MgO	2.46	2.57	2.49	2.59	2.76	2.86	2.68	2.79	2.24	2.87	3.10
CaO	8.71	8.85	9.01	8.72	7.94	7.81	8.30	8.11	7.84	7.83	7.25
Na ₂ O	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
K ₂ O	0.00	0.01	0.01	0.00	0.04	0.00	0.01	0.00	0.03	0.00	0.01
Total	99.91	99.31	99.34	99.13	99.21	99.86	100.43	101.09	100.36	98.80	100.98

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	2.96	2.98	2.96	2.96	2.96	2.96	2.97	2.97	2.97	2.96	2.98
Al iv	0.04	0.02	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.04	0.02
Al vi	1.99	1.98	1.98	1.98	1.98	1.95	1.98	2.00	2.00	1.99	2.00
Ti	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe	1.89	1.88	1.88	1.89	1.91	1.94	1.87	1.88	1.91	1.88	1.91
Mn	0.09	0.08	0.08	0.08	0.12	0.12	0.13	0.12	0.16	0.13	0.12
Mg	0.29	0.31	0.30	0.31	0.33	0.34	0.32	0.33	0.27	0.34	0.36
Ca	0.74	0.76	0.77	0.75	0.68	0.67	0.70	0.68	0.67	0.68	0.61
Na	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Alm	62.8	62.2	62.2	62.3	62.7	63.2	61.8	62.5	63.6	62.0	63.6
% Sp	3.0	2.6	2.6	2.8	4.2	4.2	4.6	4.1	5.5	4.6	4.2
% Py	10.7	11.3	10.9	11.4	12.2	12.4	11.7	12.2	9.7	12.8	13.7
% Gr	32.7	33.5	34.2	32.9	28.9	27.8	30.4	29.4	28.7	28.7	25.5

BLB97-003a Garnet (continued)

Sample	G216	G217	G218	G219	G220	G221	G223	G224	G225	G226	G227
SiO ₂	38.04	36.48	37.10	37.74	37.23	37.50	37.40	36.22	36.54	37.42	37.52
Al ₂ O ₃	21.73	21.03	21.48	21.53	21.57	21.53	21.60	21.11	21.09	21.56	21.49
TiO ₂	0.15	0.16	0.16	0.15	0.13	0.12	0.17	0.16	0.08	0.06	0.14
Cr ₂ O ₃	0.01	0.03	0.02	0.00	0.05	0.00	0.00	0.07	0.00	0.00	0.00
FeO	28.37	27.98	28.00	27.41	25.87	25.99	26.09	26.72	27.26	27.26	27.75
MnO	1.83	2.81	3.31	3.28	4.35	4.27	4.06	3.36	2.78	2.47	2.90
MgO	2.89	2.57	2.23	2.01	1.98	1.98	1.94	1.84	2.50	2.62	2.43
CaO	7.81	7.77	7.78	8.23	9.01	9.08	9.03	8.81	8.18	8.60	7.99
Na ₂ O	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.00
K ₂ O	0.00	0.01	0.00	0.02	0.00	0.00	0.03	0.05	0.00	0.01	0.02
Total	100.83	98.85	100.07	100.39	100.19	100.47	100.30	98.33	98.43	100.02	100.24

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	2.99	2.95	2.96	2.99	2.96	2.97	2.97	2.95	2.96	2.97	2.98
Al iv	0.01	0.05	0.04	0.01	0.04	0.03	0.03	0.05	0.04	0.03	0.02
Al vi	2.00	1.96	1.98	2.01	1.99	1.99	1.99	1.97	1.97	1.99	1.99
Ti	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe	1.86	1.89	1.87	1.82	1.72	1.72	1.73	1.82	1.85	1.81	1.84
Mn	0.12	0.19	0.22	0.22	0.29	0.29	0.27	0.23	0.19	0.17	0.20
Mg	0.34	0.31	0.27	0.24	0.23	0.23	0.23	0.22	0.30	0.31	0.29
Ca	0.66	0.67	0.67	0.70	0.77	0.77	0.77	0.77	0.71	0.73	0.68
Na	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Alm	62.5	61.7	61.8	61.1	57.1	57.2	57.7	59.8	60.6	60.0	61.3
% Sp	4.3	6.7	8.0	8.0	10.8	10.5	10.0	8.2	6.7	5.8	6.9
% Py	12.8	11.2	9.6	8.7	8.4	8.4	8.3	7.9	11.0	11.4	10.6
% Gr	28.3	28.1	28.2	30.7	34.1	34.4	34.4	33.8	30.4	32.0	29.2

BLB97-003a Garnet (continued)

Sample	G228	G229	G230	G231	G232
SiO ₂	36.63	38.22	36.92	37.45	37.49
Al ₂ O ₃	21.38	21.79	21.26	21.78	21.96
TiO ₂	0.13	0.12	0.10	0.08	0.04
Cr ₂ O ₃	0.00	0.06	0.00	0.05	0.02
FeO	29.20	27.28	26.99	27.54	27.43
MnO	1.63	0.99	0.86	0.79	0.74
MgO	2.97	2.89	3.19	3.12	3.35
CaO	7.61	9.67	9.52	9.50	9.68
Na ₂ O	0.01	0.02	0.00	0.00	0.00
K ₂ O	0.01	0.00	0.01	0.01	0.00
Total	99.57	101.03	98.84	100.33	100.73

Number of cations in formula based on n oxygens

n	12	12	12	12	12
Si	2.94	2.99	2.96	2.95	2.94
Al iv	0.06	0.01	0.04	0.05	0.06
Al vi	1.96	1.99	1.96	1.98	1.98
Ti	0.01	0.01	0.01	0.00	0.00
Cr	0.00	0.00	0.00	0.00	0.00
Fe	1.96	1.78	1.81	1.82	1.80
Mn	0.11	0.07	0.06	0.05	0.05
Mg	0.35	0.34	0.38	0.37	0.39
Ca	0.65	0.81	0.82	0.80	0.81
Na	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00
% Alm	63.6	59.5	59.0	59.8	58.9
% Sp	3.7	2.2	1.9	1.8	1.6
% Py	13.0	12.7	14.2	13.7	14.7
% Gr	27.0	37.1	36.4	35.9	36.3

MT98-003c Garnet

Sample	G14	G15	G16	G17	G18	G19	G20	G21	G22	G23	G24	G25	G26	G46
SiO ₂	36.39	36.20	36.37	36.60	36.39	36.48	36.78	36.69	36.62	36.78	36.57	37.21	36.58	36.78
Al ₂ O ₃	21.14	21.04	21.19	21.13	21.09	21.41	21.32	21.47	21.44	21.00	21.49	21.14	21.32	21.08
TiO ₂	0.03	0.08	0.09	0.08	0.04	0.08	0.08	0.07	0.09	0.02	0.04	0.05	0.05	0.09
Cr ₂ O ₃	0.07	0.06	0.05	0.01	0.08	0.09	0.08	0.09	0.12	0.07	0.07	0.05	0.09	0.07
FeO	29.99	30.33	30.62	30.24	30.44	30.09	30.52	30.09	29.09	29.20	30.06	30.11	29.45	29.37
MnO	0.35	0.44	0.42	0.34	0.34	0.30	0.27	0.42	0.32	0.55	0.37	0.33	0.34	0.36
MgO	3.91	3.59	3.65	3.49	3.66	3.79	4.01	4.26	4.90	5.12	4.18	4.28	4.43	3.88
CaO	6.28	6.18	6.18	6.53	6.45	6.58	6.36	6.09	5.82	5.03	6.19	6.11	5.93	6.79
Na ₂ O	0.06	0.02	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00
K ₂ O	0.03	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01
Total	98.23	97.97	98.59	98.44	98.49	98.84	99.42	99.19	98.40	97.82	98.98	99.28	98.20	98.43

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Si	2.95	2.94	2.94	2.96	2.94	2.93	2.94	2.94	2.94	2.97	2.93	2.97	2.95	2.96
Al iv	0.05	0.06	0.06	0.04	0.06	0.07	0.06	0.06	0.06	0.03	0.07	0.03	0.05	0.04
Al vi	1.96	1.96	1.96	1.97	1.95	1.96	1.95	1.96	1.97	1.96	1.97	1.96	1.97	1.96
Ti	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.01
Cr	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.00
Fe	2.03	2.06	2.07	2.04	2.06	2.02	2.04	2.01	1.95	1.97	2.02	2.01	1.98	1.98
Mn	0.02	0.03	0.03	0.02	0.02	0.02	0.02	0.03	0.02	0.04	0.03	0.02	0.02	0.02
Mg	0.47	0.44	0.44	0.42	0.44	0.45	0.48	0.51	0.59	0.62	0.50	0.51	0.53	0.47
Ca	0.54	0.54	0.54	0.57	0.56	0.57	0.54	0.52	0.50	0.43	0.53	0.52	0.51	0.59
Na	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Alm	66.1	67.2	67.3	66.9	66.8	66.0	66.2	65.5	63.8	64.4	65.6	65.6	65.0	64.8
% Sp	0.8	1.0	0.9	0.8	0.8	0.7	0.6	0.9	0.7	1.2	0.8	0.7	0.8	0.8
% Py	15.4	14.2	14.3	13.8	14.3	14.8	15.5	16.5	19.2	20.1	16.3	16.6	17.4	15.2
% Gr	17.7	17.6	17.4	18.5	18.1	18.5	17.7	17.0	16.3	14.2	17.3	17.0	16.8	19.2

MT98-003e Garnet (Continued)

Sample	G47	G48	G49	G50	G51	G52	G53	G54	G55	G56	G57	G58	G59	G65
SiO ₂	36.66	36.63	36.40	36.61	36.59	36.86	36.29	36.69	36.56	36.42	35.89	36.50	36.50	36.53
Al ₂ O ₃	21.06	21.27	21.20	21.25	21.03	21.29	21.01	20.93	20.99	20.93	20.71	20.81	20.77	20.77
TiO ₂	0.14	0.08	0.09	0.04	0.06	0.06	0.11	0.06	0.07	0.15	0.17	0.12	0.10	0.07
Cr ₂ O ₃	0.04	0.07	0.06	0.08	0.05	0.02	0.05	0.05	0.10	0.08	0.02	0.03	0.04	0.05
FeO	29.25	29.51	29.98	29.66	30.57	30.24	29.96	30.26	30.75	29.07	30.32	29.01	30.20	29.91
MnO	0.32	0.36	0.32	0.36	0.71	0.36	0.42	0.89	1.72	2.72	3.81	3.01	3.10	2.11
MgO	3.89	3.83	3.78	3.67	3.23	3.37	3.49	3.06	2.82	2.39	2.12	2.53	2.25	2.61
CaO	6.71	6.62	6.47	6.55	6.61	6.67	6.34	6.62	5.87	6.91	5.26	6.43	5.84	5.96
Na ₂ O	0.00	0.00	0.00	0.05	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.06
K ₂ O	0.02	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.00	0.01	0.00	0.00	0.02	0.02
Total	98.09	98.38	98.31	98.28	98.85	98.88	97.73	98.56	98.89	98.66	98.30	98.44	98.82	98.08

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Si	2.96	2.95	2.94	2.96	2.96	2.96	2.95	2.97	2.96	2.96	2.95	2.97	2.97	2.98
Al iv	0.04	0.05	0.06	0.04	0.04	0.04	0.05	0.03	0.04	0.04	0.05	0.03	0.03	0.02
Al vi	1.97	1.97	1.96	1.98	1.96	1.98	1.97	1.97	1.97	1.96	1.95	1.97	1.96	1.98
Ti	0.01	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.00
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00
Fe	1.98	1.99	2.03	2.00	2.07	2.03	2.04	2.05	2.08	1.97	2.08	1.97	2.06	2.04
Mn	0.02	0.02	0.02	0.02	0.05	0.02	0.03	0.06	0.12	0.19	0.26	0.21	0.21	0.15
Mg	0.47	0.46	0.46	0.44	0.39	0.40	0.42	0.37	0.34	0.29	0.26	0.31	0.27	0.32
Ca	0.58	0.57	0.56	0.57	0.57	0.57	0.55	0.57	0.51	0.60	0.46	0.56	0.51	0.52
Na	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Alm	64.9	65.3	66.1	66.0	67.2	67.0	67.0	67.1	68.3	64.7	67.8	64.8	67.4	67.5
% Sp	0.7	0.8	0.7	0.8	1.6	0.8	1.0	2.0	3.9	6.1	8.6	6.8	7.0	4.8
% Py	15.4	15.1	14.9	14.6	12.7	13.3	13.9	12.1	11.2	9.5	8.5	10.1	8.9	10.5
% Gr	19.1	18.8	18.3	18.7	18.6	18.9	18.1	18.8	16.7	19.7	15.1	18.4	16.7	17.2

Sample

Sample	G66	G67	G68	G74	G75	G76	G82	G83	G84	G85	G86	G87	G88	G89
SiO ₂	36.69	36.48	36.33	36.59	36.19	36.77	35.97	36.47	36.49	36.60	36.60	36.39	36.60	36.66
Al ₂ O ₃	20.98	20.94	20.71	20.89	20.86	21.49	20.72	21.13	20.97	21.04	21.00	20.95	21.18	21.21
TiO ₂	0.16	0.11	0.04	0.07	0.03	0.04	0.17	0.13	0.09	0.12	0.09	0.09	0.13	0.10
Cr ₂ O ₃	0.02	0.00	0.03	0.04	0.03	0.08	0.06	0.02	0.06	0.03	0.02	0.00	0.00	0.06
FeO	28.45	28.70	30.40	31.01	30.89	33.22	32.51	30.39	30.46	30.88	31.38	30.52	31.20	30.17
MnO	2.78	2.51	3.02	3.09	3.05	3.08	2.70	2.45	1.39	1.32	1.36	1.17	1.04	0.40
MgO	2.80	2.65	2.38	2.29	2.30	3.24	2.31	2.37	2.95	2.94	3.02	2.87	3.20	3.58
CaO	6.81	6.88	5.59	5.03	4.94	2.51	3.47	6.44	5.93	6.03	5.87	6.38	6.00	6.43
Na ₂ O	0.01	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00
K ₂ O	0.00	0.01	0.03	0.00	0.02	0.00	0.02	0.01	0.00	0.01	0.00	0.00	0.00	0.01
Total	98.70	98.31	98.54	99.02	98.30	100.44	97.93	99.41	98.34	98.95	99.38	98.37	99.36	98.62

Number of cations in formula based on n oxygens

[illegible]

MT98-003e Garnet (Continued)

Sample	G90	G91	G114	G119	G120	G121	G122	G132	G133	G134	G135	G139	G140	G141
SiO ₂	36.54	36.70	32.21	37.11	36.87	36.85	36.84	33.76	36.21	36.95	35.85	36.48	36.74	36.51
Al ₂ O ₃	21.12	21.26	9.22	21.29	21.19	21.22	21.28	16.12	20.79	21.07	20.66	21.22	21.12	21.01
TiO ₂	0.07	0.08	0.04	0.12	0.10	0.14	0.14	0.09	0.06	0.10	0.02	0.10	0.09	0.11
Cr ₂ O ₃	0.03	0.04	0.05	0.01	0.00	0.02	0.05	0.02	0.00	0.02	0.00	0.05	0.00	0.06
FeO	30.04	30.49	46.82	29.30	29.29	29.74	28.94	18.96	31.15	29.88	30.82	31.01	31.40	30.38
MnO	0.36	0.44	0.06	0.69	0.62	0.68	2.71	2.33	5.24	2.20	4.84	1.05	1.08	1.12
MgO	3.50	3.36	0.01	4.48	4.52	4.51	2.70	5.46	2.21	2.94	2.64	2.95	3.09	3.08
CaO	6.64	6.69	0.27	5.97	6.06	5.96	6.34	0.98	2.82	5.72	2.87	6.36	5.58	6.36
Na ₂ O	0.00	0.00	1.29	0.01	0.00	0.00	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00
K ₂ O	0.00	0.00	4.08	0.01	0.01	0.00	0.01	1.95	0.00	0.00	0.00	0.00	0.02	0.00
Total	98.28	99.07	94.04	98.99	98.65	99.10	99.02	79.95	98.49	98.88	97.68	99.23	99.12	98.63

Number of cations in formula based on n oxygens														
n	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Si	2.96	2.95	3.11	2.96	2.96	2.95	2.97	3.25	2.97	2.98	2.96	2.94	2.96	2.96
Al iv	0.04	0.05	-0.11	0.04	0.04	0.05	0.03	-0.25	0.03	0.02	0.04	0.06	0.04	0.04
Al vi	1.97	1.97	1.16	1.97	1.96	1.95	1.99	2.08	1.99	1.99	1.98	1.96	1.97	1.96
Ti	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.01	0.01	0.01
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe	2.03	2.05	3.78	1.96	1.96	1.99	1.95	1.53	2.14	2.02	2.13	2.09	2.12	2.06
Mn	0.02	0.03	0.00	0.05	0.04	0.05	0.19	0.19	0.36	0.15	0.34	0.07	0.07	0.08
Mg	0.42	0.40	0.00	0.53	0.54	0.54	0.32	0.78	0.27	0.35	0.33	0.36	0.37	0.37
Ca	0.58	0.58	0.03	0.51	0.52	0.51	0.55	0.10	0.25	0.49	0.25	0.55	0.48	0.55
Na	0.00	0.00	0.24	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.00
%Alm	66.6	67.0	99.1	64.2	64.0	64.5	64.9	58.7	70.8	66.9	69.9	68.2	69.6	67.3
%Sp	0.8	1.0	0.1	1.5	1.4	1.5	6.2	7.3	12.1	5.0	11.1	2.3	2.4	2.5
%Py	13.8	13.2	0.0	17.5	17.6	17.4	10.8	30.1	9.0	11.7	10.7	11.6	12.2	12.1
%Gr	18.8	18.8	0.7	16.8	17.0	16.6	18.2	3.9	8.2	16.4	8.3	17.9	15.8	18.0

MT98-003e Garnet (Continued)

Sample	G142	G143	G144	G145	G157	G159	G170	G171	G172	G173	G179	G180	G187	G188
SiO ₂	36.75	36.95	36.47	37.00	37.53	36.86	39.37	36.67	37.05	36.63	36.61	36.22	36.38	37.12
Al ₂ O ₃	20.92	21.18	21.15	21.20	21.42	21.18	22.24	21.21	21.03	21.11	21.03	20.89	20.88	21.22
TiO ₂	0.11	0.10	0.06	0.06	0.08	0.08	0.06	0.11	0.09	0.10	0.05	0.07	0.05	0.03
Cr ₂ O ₃	0.01	0.00	0.00	0.00	0.00	0.04	0.03	0.04	0.00	0.00	0.00	0.00	0.02	0.00
FeO	30.69	30.98	31.51	30.91	29.78	29.45	25.90	31.49	30.77	30.69	30.41	30.43	30.80	30.38
MnO	1.04	1.09	0.91	0.53	0.39	2.18	4.07	0.77	0.76	0.67	4.19	2.66	3.48	3.18
MgO	3.01	3.02	3.13	3.56	3.69	2.76	1.97	3.27	3.18	3.29	2.21	2.73	2.80	2.81
CaO	6.18	6.24	5.69	5.56	6.50	6.14	5.76	5.67	6.37	6.29	4.78	5.26	3.62	4.50
Na ₂ O	0.00	0.00	0.00	0.00	0.00	0.01	0.82	0.00	0.00	0.00	0.02	0.00	0.00	0.00
K ₂ O	0.00	0.00	0.01	0.00	0.01	0.00	0.44	0.00	0.00	0.00	0.02	0.03	0.00	0.00
Total	98.71	99.56	98.93	98.83	99.40	98.70	100.64	99.23	99.25	98.77	99.33	98.30	98.04	99.24

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Si	2.97	2.97	2.95	2.98	2.99	2.98	3.08	2.95	2.98	2.96	2.97	2.96	2.98	2.99
Al iv	0.03	0.03	0.05	0.02	0.01	0.02	-0.08	0.05	0.02	0.04	0.03	0.04	0.02	0.01
Al vi	1.97	1.97	1.97	1.99	2.00	2.00	2.13	1.97	1.97	1.97	1.98	1.97	1.99	2.01
Ti	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe	2.08	2.08	2.13	2.08	1.98	1.99	1.69	2.12	2.07	2.07	2.06	2.08	2.11	2.05
Mn	0.07	0.07	0.06	0.04	0.03	0.15	0.27	0.05	0.05	0.05	0.29	0.18	0.24	0.22
Mg	0.36	0.36	0.38	0.43	0.44	0.33	0.23	0.39	0.38	0.40	0.27	0.33	0.34	0.34
Ca	0.54	0.54	0.49	0.48	0.55	0.53	0.48	0.49	0.55	0.54	0.42	0.46	0.32	0.39
Na	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Alm	68.1	68.1	69.6	68.8	66.1	66.3	63.3	69.4	67.8	67.8	68.0	68.0	70.1	68.5
% Sp	2.3	2.4	2.0	1.2	0.9	5.0	10.1	1.7	1.7	1.5	9.5	6.0	8.0	7.3
% Py	11.9	11.8	12.3	14.1	14.6	11.1	8.6	12.9	12.5	12.9	8.8	10.9	11.4	11.3
% Gr	17.6	17.6	16.1	15.9	18.5	17.7	18.0	16.0	18.0	17.8	13.7	15.1	10.6	13.0

MT98-003c Garnet (Continued)

Sample	G189	G190	G191	G192	G193	G194	G195	G197	G198	G200	G201	G202	G203	G204
SiO ₂	36.89	36.90	36.60	36.91	36.75	36.75	36.78	37.04	37.21	36.72	36.89	36.64	36.90	36.75
Al ₂ O ₃	21.16	21.29	21.02	21.38	21.12	20.99	21.13	21.02	20.90	21.04	21.06	21.16	21.00	21.15
TiO ₂	0.04	0.11	0.09	0.05	0.11	0.10	0.12	0.12	0.06	0.12	0.09	0.09	0.09	0.08
Cr ₂ O ₃	0.03	0.08	0.07	0.04	0.05	0.00	0.01	0.06	0.02	0.03	0.04	0.04	0.09	0.02
FeO	30.94	31.60	30.61	30.40	30.42	30.05	30.34	29.62	30.19	28.49	29.18	29.71	29.63	29.39
MnO	2.41	0.90	0.94	0.88	0.68	0.74	1.10	0.32	0.35	0.34	0.34	0.35	0.28	0.32
MgO	2.92	3.50	3.32	3.23	3.41	3.48	3.06	3.36	3.54	3.41	3.42	3.56	3.56	3.71
CaO	4.84	5.56	5.85	6.30	6.06	6.18	6.26	7.02	6.70	7.19	7.15	6.52	6.73	6.55
Na ₂ O	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.02	0.00	0.00	0.00	0.00
K ₂ O	0.02	0.00	0.00	0.01	0.01	0.00	0.03	0.00	0.02	0.13	0.00	0.00	0.00	0.00
Total	99.26	99.94	98.50	99.21	98.61	98.30	98.84	98.55	99.00	97.50	98.17	98.09	98.28	97.97

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Si	2.98	2.95	2.96	2.96	2.97	2.97	2.97	2.98	2.99	2.98	2.98	2.96	2.98	2.97
Al iv	0.02	0.05	0.04	0.04	0.03	0.03	0.03	0.02	0.01	0.02	0.02	0.04	0.02	0.03
Al vi	1.99	1.96	1.97	1.99	1.98	1.97	1.98	1.98	1.96	1.99	1.98	1.98	1.97	1.99
Ti	0.00	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01
Cr	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Fe	2.09	2.11	2.07	2.04	2.05	2.03	2.05	1.99	2.03	1.93	1.97	2.01	2.00	1.99
Mn	0.16	0.06	0.06	0.06	0.05	0.05	0.08	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Mg	0.35	0.42	0.40	0.39	0.41	0.42	0.37	0.40	0.42	0.41	0.41	0.43	0.43	0.45
Ca	0.42	0.48	0.51	0.54	0.52	0.54	0.54	0.61	0.58	0.62	0.62	0.57	0.58	0.57
Na	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
% Alm	69.1	68.9	68.1	67.4	67.7	66.9	67.5	65.9	66.4	64.6	65.2	66.4	66.0	65.7
% Sp	5.5	2.0	2.1	2.0	1.5	1.7	2.5	0.7	0.8	0.8	0.8	0.8	0.6	0.7
% Py	11.6	13.6	13.2	12.8	13.5	13.8	12.1	13.3	13.9	13.8	13.6	14.2	14.1	14.8
% Gr	13.8	15.5	16.7	17.9	17.3	17.6	17.9	20.0	18.9	20.9	20.4	18.7	19.2	18.8

MT98-003e Garnet (Continued)

Sample	G205	G206	G207	G208	G209	G210	G211	G212	G213	G214	G215	G216	G217	G218
SiO ₂	36.82	37.11	37.25	36.87	36.76	37.08	36.63	37.11	36.92	37.48	36.58	37.16	36.66	36.85
Al ₂ O ₃	21.21	21.25	21.22	20.81	21.08	20.94	20.95	20.97	20.95	20.96	20.63	21.16	21.03	21.15
TiO ₂	0.12	0.06	0.09	0.06	0.08	0.11	0.11	0.08	0.11	0.10	0.08	0.11	0.06	0.09
Cr ₂ O ₃	0.04	0.01	0.08	0.03	0.04	0.08	0.04	0.04	0.07	0.05	0.08	0.08	0.02	0.05
FeO	29.00	28.99	29.15	30.16	30.79	29.82	29.63	30.69	30.35	30.62	26.40	29.17	29.23	29.96
MnO	0.36	0.37	0.48	1.23	1.12	0.98	0.77	0.78	0.45	0.47	0.35	0.39	0.36	0.42
MgO	4.25	4.46	4.68	3.11	3.16	3.01	2.99	3.20	3.30	3.36	2.55	3.32	3.59	3.72
CaO	6.32	5.97	5.79	5.92	5.52	6.75	6.95	5.88	6.39	6.45	6.86	6.98	6.73	6.69
Na ₂ O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00
K ₂ O	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.02	0.00	0.01	0.00
Total	98.13	98.21	98.73	98.20	98.55	98.79	98.08	98.75	98.54	99.48	93.69	98.37	97.70	98.93

Number of cations in formula based on n oxygens				
n	12	12	12	12
Si	2.97	2.98	2.98	2.98
Al iv	0.03	0.02	0.02	0.02
Al vi	1.98	1.99	1.98	1.97
Ti	0.01	0.00	0.01	0.01
Cr	0.00	0.00	0.00	0.00
Fe	1.95	1.95	1.95	1.95
Mn	0.02	0.02	0.03	0.03
Mg	0.51	0.53	0.56	0.56
Ca	0.55	0.51	0.50	0.50
Na	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00
% Alm	64.4	64.5	64.2	64.2
% Sp	0.8	0.8	1.1	1.1
% Py	16.8	17.7	18.4	18.4
% Gr	18.0	17.0	16.3	16.3

	12	12	12	12
	2.97	2.99	2.97	2.99
	0.01	0.01	0.03	0.01
	1.98	1.98	1.98	1.97
	0.01	0.01	0.01	0.01
	0.00	0.00	0.00	0.00
	1.95	2.01	2.01	2.05
	0.08	0.07	0.05	0.03
	0.38	0.36	0.36	0.40
	0.48	0.58	0.60	0.55
	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00
	67.7	66.5	66.4	67.6
	2.8	2.2	1.7	1.0
	12.5	12.0	11.9	13.1
	17.0	19.3	19.9	18.2
	65.7	65.5	65.9	65.7
	0.8	0.8	0.9	0.9
	14.3	14.3	11.3	14.6
	19.3	19.3	21.9	18.8

MT98-003e Giamet (Continued)

Sample	G219	G220	G221	G222	G223	G224	G225	G226	G227	G228	G229	G230	G231	G232
SiO ₂	37.26	36.82	37.32	37.15	36.95	36.96	36.96	36.88	37.03	36.93	36.90	37.12	37.04	36.77
Al ₂ O ₃	21.19	20.99	21.24	21.09	21.11	20.96	20.97	20.88	21.02	20.89	21.09	21.14	21.01	21.01
TiO ₂	0.04	0.11	0.03	0.08	0.06	0.06	0.07	0.12	0.10	0.07	0.13	0.12	0.10	0.13
Cr ₂ O ₃	0.04	0.03	0.01	0.09	0.01	0.03	0.06	0.00	0.05	0.00	0.02	0.01	0.04	0.07
FeO	29.72	29.27	29.56	29.83	29.57	30.34	30.07	30.36	30.33	30.30	30.64	30.29	29.77	30.02
MnO	0.30	0.32	0.35	0.40	0.36	0.37	0.47	0.58	0.66	0.67	0.77	0.89	0.99	0.97
MgO	3.94	3.94	4.12	3.67	3.43	3.42	3.37	3.36	3.37	3.23	3.22	3.05	3.10	3.01
CaO	6.18	6.25	6.11	6.43	6.55	6.42	6.08	5.98	5.87	5.83	6.20	6.25	6.18	6.31
Na ₂ O	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K ₂ O	0.00	0.02	0.00	0.02	0.00	0.01	0.00	0.02	0.02	0.00	0.00	0.02	0.00	0.00
Total	98.67	97.77	98.73	98.76	98.05	98.55	98.07	98.19	98.44	97.92	98.97	98.89	98.23	98.28

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Si	2.99	2.98	2.99	2.98	2.99	2.98	2.99	2.99	2.99	3.00	2.97	2.99	3.00	2.98
Al iv	0.01	0.02	0.01	0.02	0.01	0.02	0.01	0.01	0.01	0.00	0.03	0.01	0.00	0.02
Al vi	1.99	1.98	1.99	1.98	2.00	1.97	1.99	1.98	1.99	2.00	1.97	1.99	2.00	1.98
Ti	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.01	0.01	0.01
Cr	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe	1.99	1.98	1.98	2.00	2.00	2.05	2.04	2.06	2.05	2.06	2.06	2.04	2.01	2.03
Mn	0.02	0.02	0.02	0.03	0.02	0.03	0.03	0.04	0.04	0.05	0.05	0.06	0.07	0.07
Mg	0.47	0.48	0.49	0.44	0.41	0.41	0.41	0.41	0.41	0.39	0.39	0.37	0.37	0.36
Ca	0.53	0.54	0.52	0.55	0.57	0.55	0.53	0.52	0.51	0.51	0.53	0.54	0.54	0.55
Na	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Alm	66.1	65.6	65.6	66.3	66.5	67.4	67.8	68.1	68.1	68.5	67.9	67.9	67.3	67.5
% Sp	0.7	0.7	0.8	0.9	0.8	0.8	1.1	1.3	1.5	1.5	1.7	2.0	2.3	2.2
% Py	15.6	15.7	16.3	14.5	13.7	13.5	13.5	13.4	13.5	13.0	12.7	12.2	12.5	12.1
% Gr	17.6	18.0	17.4	18.3	18.9	18.3	17.6	17.2	16.9	16.9	17.6	17.9	17.9	18.2

MT98-003e Garnet (Continued)

Sample	G233	G234	G235	G236	G237	G238	G239	G240	G241	G242	G243	G244	G245	G246
SiO ₂	36.46	36.47	36.63	36.83	37.05	36.90	36.98	37.00	36.81	36.83	36.65	36.64	36.60	36.53
Al ₂ O ₃	20.49	20.97	20.77	21.05	20.73	20.91	21.23	20.89	21.03	21.08	20.91	21.03	20.89	20.94
TiO ₂	0.13	0.08	0.13	0.07	0.06	0.10	0.12	0.06	0.14	0.09	0.15	0.14	0.08	0.09
Cr ₂ O ₃	0.05	0.03	0.02	0.05	0.04	0.06	0.00	0.00	0.00	0.03	0.04	0.00	0.02	0.01
FeO	30.30	30.14	29.80	30.52	30.31	30.38	30.16	29.71	29.60	30.36	29.71	29.06	30.05	30.17
MnO	1.13	1.19	1.01	1.02	0.78	0.61	0.57	0.98	0.75	0.68	0.60	0.76	1.00	0.97
MgO	0.00	2.97	2.96	3.20	3.17	3.28	3.62	3.67	3.55	3.50	3.32	3.05	3.23	3.04
CaO	5.89	6.08	6.30	5.65	6.04	5.94	5.94	5.83	5.83	5.80	6.16	6.92	5.46	6.04
Na ₂ O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K ₂ O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.02	0.01	0.02	0.00	0.00
Total	94.45	97.93	97.62	98.38	98.17	98.18	98.61	98.14	97.72	98.39	97.54	97.62	97.33	97.80

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Si	3.08	2.97	2.99	2.98	3.00	2.99	2.98	2.99	2.99	2.98	2.98	2.98	2.99	2.98
Al iv	-0.08	0.03	0.01	0.02	0.00	0.01	0.02	0.01	0.01	0.02	0.02	0.02	0.01	0.02
Al vi	2.12	1.98	1.98	1.99	1.98	1.98	1.99	1.98	2.00	1.98	1.99	1.99	2.00	1.99
Ti	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.01
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe	2.14	2.05	2.03	2.07	2.05	2.06	2.03	2.01	2.01	2.05	2.02	1.98	2.05	2.06
Mn	0.08	0.08	0.07	0.07	0.05	0.04	0.04	0.07	0.05	0.05	0.04	0.05	0.07	0.07
Mg	0.00	0.36	0.36	0.39	0.38	0.40	0.43	0.44	0.43	0.42	0.40	0.37	0.39	0.37
Ca	0.53	0.53	0.55	0.49	0.52	0.52	0.51	0.50	0.51	0.50	0.54	0.60	0.48	0.53
Na	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Alm	77.7	67.8	67.5	68.6	68.1	68.3	67.3	66.4	67.0	67.9	67.4	65.8	68.6	68.1
% Sp	2.9	2.7	2.3	2.3	1.8	1.4	1.3	2.2	1.7	1.5	1.4	1.8	2.3	2.2
% Py	0.0	11.9	12.0	12.8	12.7	13.2	14.4	14.6	14.3	14.0	13.4	12.3	13.1	12.2
% Gr	19.3	17.5	18.3	16.3	17.4	17.1	17.0	16.7	16.9	16.6	17.9	20.1	16.0	17.5

MT98-003c Garnet (Continued)

Sample	G247	G248	G249	G250
SiO ₂	36.42	36.90	37.14	36.69
Al ₂ O ₃	20.93	21.08	21.16	21.15
TiO ₂	0.11	0.11	0.06	0.11
Cr ₂ O ₃	0.02	0.01	0.07	0.08
FeO	30.66	30.36	29.48	29.26
MnO	1.01	0.62	0.39	0.25
MgO	3.20	3.22	3.72	4.03
CaO	5.50	6.04	6.37	6.20
Na ₂ O	0.00	0.00	0.00	0.00
K ₂ O	0.00	0.01	0.02	0.00
Total	97.85	98.36	98.41	97.77

Number of cations in formula based on n oxygens

n	12	12	12	12
Si	2.97	2.98	2.99	2.97
Al iv	0.03	0.02	0.01	0.03
Al vi	1.98	1.99	1.99	1.98
Ti	0.01	0.01	0.00	0.01
Cr	0.00	0.00	0.00	0.00
Fe	2.09	2.05	1.98	1.98
Mn	0.07	0.04	0.03	0.02
Mg	0.39	0.39	0.45	0.49
Ca	0.48	0.52	0.55	0.54
Na	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00
% Alm	69.0	68.3	66.0	65.5
% Sp	2.3	1.4	0.9	0.6
% Py	12.9	12.9	14.9	16.1
% Gr	15.9	17.4	18.3	17.8

BLB97-003e Biotite

Sample	B1	B2	B3	B28	B29	B30	B31	B35	B36	B37	B38	B39	B97	B98
SiO ₂	35.76	35.44	34.26	34.87	34.84	35.93	35.28	35.38	35.44	37.04	38.17	35.96	35.05	33.11
Al ₂ O ₃	18.14	18.85	18.68	19.07	19.81	19.93	19.15	18.67	18.27	18.32	19.17	17.35	19.47	18.92
TiO ₂	1.64	1.55	1.68	1.47	1.50	1.63	1.42	1.66	1.67	1.50	1.51	1.52	1.31	1.15
Cr ₂ O ₃	0.14	0.06	0.20	0.14	0.10	0.08	0.11	0.07	0.04	0.08	0.03	0.15	0.02	0.10
FeO	15.68	15.20	15.80	14.98	14.62	15.34	15.48	15.31	15.70	15.06	14.68	14.76	16.50	17.96
MnO	0.06	0.00	0.10	0.05	0.07	0.02	0.08	0.13	0.08	0.11	0.04	0.05	0.08	0.04
K ₂ O	8.58	8.60	8.58	8.72	8.94	8.88	8.91	8.58	8.84	8.22	8.47	8.24	8.51	6.31
MgO	12.66	12.20	11.82	11.86	11.80	11.75	12.04	12.14	12.42	12.75	12.91	11.59	12.23	12.50
CaO	0.00	0.00	0.03	0.03	0.03	0.00	0.00	0.01	0.02	0.07	0.05	0.15	0.07	0.07
Na ₂ O	0.16	0.15	0.14	0.20	0.18	0.10	0.14	0.12	0.08	0.09	0.17	0.16	0.26	0.18
Cl	0.13	0.08	0.05	0.08	0.09	0.09	0.03	0.12	0.07	0.09	0.08	0.09	0.13	0.08
BaO	0.13	0.46	0.40	0.15	0.09	0.32	0.08	0.25	0.17	0.19	0.28	0.26	0.28	0.42
Total	93.08	92.60	91.75	91.61	92.07	94.07	92.72	92.46	92.81	93.53	95.55	90.27	93.90	90.83

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Si	2.98	2.96	2.91	2.94	2.92	2.95	2.95	2.96	2.96	3.04	3.05	2.90	2.90	2.84
Al iv	1.02	1.04	1.09	1.06	1.08	1.05	1.05	1.04	1.04	0.96	0.95	1.10	1.10	1.16
Al vi	0.76	0.82	0.78	0.84	0.88	0.88	0.83	0.81	0.76	0.81	0.86	0.80	0.80	0.75
Ti	0.10	0.10	0.11	0.09	0.09	0.10	0.09	0.10	0.11	0.09	0.09	0.08	0.08	0.07
Cr	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.01
Fe	1.09	1.06	1.12	1.06	1.03	1.05	1.08	1.07	1.10	1.03	0.98	1.14	1.14	1.29
Mn	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.00
K	0.91	0.92	0.93	0.94	0.96	0.93	0.95	0.92	0.94	0.86	0.86	0.90	0.90	0.69
Mg	1.57	1.52	1.50	1.49	1.48	1.44	1.50	1.52	1.55	1.56	1.54	1.51	1.51	1.60
Ca	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.01
Na	0.03	0.02	0.02	0.03	0.03	0.02	0.02	0.02	0.01	0.01	0.03	0.04	0.04	0.03
Cl	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.00
Ba	0.00	0.02	0.01	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Fe/(Fe+Mg)	0.41	0.41	0.43	0.41	0.41	0.42	0.42	0.41	0.41	0.40	0.39	0.43	0.43	0.45

BLB97-003e Biotite (Continued)

Sample	B99	B100	B106	B107	B118	B127	B146	B147	B148	B155	B156	B162	B163	B164
SiO ₂	35.40	35.30	34.10	35.38	34.54	35.34	35.39	35.74	35.21	35.46	35.97	34.47	33.19	34.76
Al ₂ O ₃	19.42	19.22	19.11	19.61	20.50	19.43	18.25	18.59	18.45	18.57	19.19	18.71	18.25	19.70
TiO ₂	1.52	1.50	0.91	1.11	0.89	1.14	1.53	1.55	1.68	1.59	1.61	1.30	1.48	1.19
Cr ₂ O ₃	0.06	0.09	0.00	0.11	0.07	0.01	0.04	0.10	0.03	0.03	0.15	0.17	0.06	0.20
FeO	15.69	15.59	17.36	16.82	20.24	16.49	15.75	15.41	15.90	15.37	15.43	18.33	19.24	19.15
MnO	0.04	0.12	0.06	0.06	0.12	0.10	0.07	0.05	0.09	0.00	0.00	0.05	0.05	0.11
K ₂ O	8.61	8.72	7.12	8.59	6.04	8.73	8.54	8.46	8.91	8.91	8.74	8.34	8.14	6.62
MgO	11.92	12.00	12.04	11.87	12.10	11.84	12.12	12.36	12.05	12.31	12.04	11.21	10.81	12.07
CaO	0.05	0.00	0.12	0.00	0.08	0.06	0.03	0.05	0.00	0.01	0.01	0.02	0.03	0.05
Na ₂ O	0.26	0.22	0.12	0.15	0.08	0.17	0.16	0.16	0.20	0.05	0.10	0.06	0.00	0.08
Cl	0.11	0.11	0.08	0.11	0.09	0.07	0.07	0.07	0.14	0.07	0.08	0.10	0.07	0.07
BaO	0.40	0.11	0.11	0.26	0.10	0.23	0.06	0.04	0.13	0.34	0.23	0.46	0.17	0.44
Total	93.49	92.98	91.13	94.05	94.85	93.61	92.02	92.59	92.79	92.71	93.55	93.22	91.51	94.43

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Si	2.94	2.94	2.90	2.93	2.84	2.94	2.98	2.97	2.95	2.97	2.97	2.91	2.87	2.87
Al iv	1.06	1.06	1.10	1.07	1.16	1.06	1.02	1.03	1.05	1.03	1.03	1.09	1.13	1.13
Al vi	0.84	0.83	0.82	0.84	0.83	0.84	0.79	0.80	0.78	0.80	0.84	0.77	0.72	0.79
Ti	0.09	0.09	0.06	0.07	0.05	0.07	0.10	0.10	0.11	0.10	0.10	0.08	0.10	0.07
Cr	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.00	0.01
Fe	1.09	1.09	1.24	1.16	1.39	1.15	1.11	1.07	1.11	1.08	1.07	1.29	1.39	1.32
Mn	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.01
K	0.91	0.93	0.77	0.91	0.63	0.93	0.92	0.90	0.95	0.95	0.92	0.90	0.90	0.70
Mg	1.47	1.49	1.53	1.46	1.48	1.47	1.52	1.53	1.51	1.54	1.48	1.41	1.39	1.49
Ca	0.00	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Na	0.04	0.03	0.02	0.02	0.01	0.03	0.03	0.03	0.03	0.01	0.02	0.01	0.00	0.01
Cl	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00
Ba	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.02	0.01	0.01
Fe/(Fe+Mg)	0.42	0.42	0.45	0.44	0.48	0.44	0.42	0.41	0.43	0.41	0.42	0.48	0.50	0.47

BLB97-003e Biotite (Continued)

Sample	B165	B181	B182	B183	B184	B185	B186	B187	B188	B189	B190	B191	B192	B193
SiO ₂	34.79	33.81	32.78	35.16	35.45	36.68	36.19	34.10	35.18	35.39	35.93	35.50	35.91	35.78
Al ₂ O ₃	19.07	18.39	18.42	19.11	18.87	18.16	18.18	18.73	18.47	19.03	18.66	18.64	18.34	18.50
TiO ₂	1.14	1.42	1.49	1.24	1.47	1.40	1.49	1.45	1.56	1.51	1.63	1.57	1.59	1.40
Cr ₂ O ₃	0.14	0.03	0.00	0.06	0.02	0.04	0.05	0.10	0.10	0.06	0.18	0.08	0.07	0.03
FeO	19.11	22.42	24.09	16.44	15.93	14.95	15.08	14.48	14.64	14.54	15.30	15.48	15.11	14.61
MnO	0.02	0.11	0.05	0.06	0.06	0.12	0.09	0.08	0.08	0.14	0.15	0.05	0.03	0.06
K ₂ O	7.27	7.76	6.56	8.27	8.70	8.27	8.32	7.42	8.24	8.69	8.73	8.37	8.09	8.33
MgO	12.04	8.76	9.31	11.91	12.01	12.80	12.42	11.91	12.54	12.62	12.56	12.74	12.95	12.72
CaO	0.04	0.07	0.07	0.03	0.00	0.01	0.04	0.10	0.03	0.03	0.03	0.05	0.00	0.02
Na ₂ O	0.10	0.08	0.08	0.18	0.15	0.13	0.17	0.15	0.13	0.11	0.16	0.15	0.13	0.18
Cl	0.09	0.14	0.14	0.09	0.05	0.07	0.10	0.08	0.06	0.10	0.08	0.06	0.04	0.10
BaO	0.30	0.17	0.02	0.16	0.25	0.18	0.31	0.29	0.21	0.00	0.20	0.16	0.20	0.23
Total	94.11	93.15	93.00	92.70	92.94	92.82	92.45	88.89	91.23	92.23	93.61	92.87	92.45	91.95

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Si	2.89	2.91	2.83	2.94	2.96	3.03	3.02	2.95	2.97	2.96	2.97	2.95	2.99	3.00
Al iv	1.11	1.09	1.17	1.06	1.04	0.97	0.98	1.05	1.03	1.04	1.03	1.05	1.01	1.00
Al vi	0.76	0.77	0.70	0.83	0.81	0.81	0.81	0.86	0.80	0.83	0.79	0.78	0.78	0.82
Ti	0.07	0.09	0.10	0.08	0.09	0.09	0.09	0.09	0.10	0.09	0.10	0.10	0.10	0.09
Cr	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.01	0.00	0.00
Fe	1.33	1.61	1.74	1.15	1.11	1.03	1.05	1.05	1.03	1.02	1.06	1.08	1.05	1.02
Mn	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00
K	0.77	0.85	0.72	0.88	0.93	0.87	0.89	0.82	0.89	0.93	0.92	0.89	0.86	0.89
Mg	1.49	1.12	1.20	1.49	1.49	1.58	1.54	1.53	1.58	1.57	1.55	1.58	1.61	1.59
Ca	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Na	0.02	0.01	0.01	0.03	0.02	0.02	0.03	0.03	0.02	0.02	0.03	0.02	0.02	0.03
Cl	0.00	0.01	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.01
Ba	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01
Fe/(Fe+Mg)	0.47	0.59	0.59	0.44	0.43	0.40	0.41	0.41	0.40	0.39	0.41	0.41	0.40	0.39

BLB97-003e Biotite (Continued)

Sample	B194	B195	B196	B197	B198	B199	B200	B201	B202	B203	B204	B205	B206	B207
SiO ₂	35.50	35.59	36.44	35.61	35.82	35.54	34.83	34.97	34.94	36.01	36.10	35.14	32.73	34.82
Al ₂ O ₃	19.88	18.76	18.86	18.90	19.51	18.52	18.86	18.92	18.74	17.82	18.09	19.12	18.45	18.98
TiO ₂	1.52	1.41	1.37	1.39	1.33	1.91	1.84	1.60	1.57	1.50	1.61	1.18	1.09	1.55
Cr ₂ O ₃	0.12	0.00	0.08	0.00	0.03	0.03	0.09	0.04	0.03	0.08	0.02	0.08	0.06	0.00
FeO	13.91	14.16	14.23	14.16	13.64	14.56	14.90	14.76	14.69	16.09	15.74	17.04	17.25	15.77
MnO	0.12	0.07	0.10	0.07	0.07	0.13	0.08	0.11	0.06	0.00	0.06	0.06	0.07	0.12
K ₂ O	8.54	8.71	8.67	8.52	8.74	8.66	9.06	8.59	8.53	8.48	8.93	7.26	6.40	8.36
MgO	11.73	12.83	13.16	12.86	13.05	12.54	12.34	12.67	12.41	12.34	12.28	13.35	13.42	12.10
CaO	0.05	0.11	0.05	0.01	0.00	0.01	0.05	0.00	0.00	0.01	0.04	0.04	0.06	0.10
Na ₂ O	0.12	0.18	0.17	0.20	0.24	0.15	0.16	0.13	0.18	0.12	0.06	0.09	0.17	0.15
Cl	0.06	0.06	0.11	0.07	0.04	0.05	0.05	0.08	0.06	0.08	0.05	0.12	0.07	0.08
BaO	0.04	0.23	0.14	0.02	0.47	0.31	0.10	0.00	0.00	0.04	0.21	0.08	0.16	0.35
Total	91.58	92.08	93.38	91.82	92.94	92.40	92.37	91.87	91.20	92.56	93.19	93.56	89.94	92.37

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Si	2.97	2.97	2.99	2.98	2.96	2.97	2.92	2.94	2.95	3.01	3.00	2.90	2.83	2.93
Al iv	1.03	1.03	1.01	1.02	1.04	1.03	1.08	1.06	1.05	0.99	1.00	1.10	1.17	1.07
Al vi	0.92	0.81	0.82	0.84	0.86	0.79	0.79	0.81	0.81	0.77	0.77	0.76	0.71	0.81
Ti	0.10	0.09	0.08	0.09	0.08	0.12	0.12	0.10	0.10	0.09	0.10	0.07	0.07	0.10
Cr	0.01	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.00
Fe	0.97	0.99	0.98	0.99	0.94	1.02	1.05	1.04	1.04	1.12	1.09	1.17	1.25	1.11
Mn	0.01	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.01
K	0.91	0.93	0.91	0.91	0.92	0.92	0.97	0.92	0.92	0.90	0.95	0.76	0.71	0.90
Mg	1.46	1.59	1.61	1.60	1.61	1.56	1.54	1.59	1.56	1.54	1.52	1.64	1.73	1.52
Ca	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Na	0.02	0.03	0.03	0.03	0.04	0.02	0.03	0.02	0.03	0.02	0.01	0.01	0.03	0.02
Cl	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Ba	0.00	0.01	0.00	0.00	0.02	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01
Fe/(Fe+Mg)	0.40	0.38	0.38	0.38	0.37	0.39	0.40	0.40	0.40	0.42	0.42	0.42	0.42	0.42

BLB97-003e Rhotite (Continued)

Sample	B208	B209	B211	B212	B213	B215	B219	B222	B223	B224	B225	B226	B227	B228
SiO ₂	34.48	34.61	36.31	35.91	35.58	35.46	32.62	34.91	34.32	35.23	35.66	35.34	35.61	35.75
Al ₂ O ₃	18.23	18.12	18.57	19.18	18.37	19.44	18.74	19.61	18.92	18.35	19.02	18.86	18.66	18.89
TiO ₂	1.67	1.28	1.68	1.83	1.53	1.67	1.38	1.30	1.29	1.59	1.49	1.46	1.56	1.53
Cr ₂ O ₃	0.12	0.09	0.07	0.07	0.06	0.10	0.15	0.03	0.00	0.12	0.05	0.10	0.05	0.10
FeO	15.48	16.41	14.91	15.91	15.41	15.54	17.17	15.98	16.48	15.38	15.30	15.59	15.13	15.64
MnO	0.06	0.06	0.04	0.09	0.06	0.03	0.09	0.06	0.09	0.10	0.08	0.13	0.10	0.17
K ₂ O	8.61	7.21	8.17	8.60	8.32	8.36	6.95	8.14	7.82	8.57	8.59	8.43	8.46	8.53
MgO	11.58	12.54	12.82	12.10	12.53	12.26	12.90	11.63	12.05	11.83	12.14	12.41	12.16	12.48
CaO	0.05	0.12	0.06	0.01	0.05	0.07	0.03	0.03	0.01	0.00	0.03	0.01	0.03	0.01
Na ₂ O	0.14	0.15	0.16	0.21	0.18	0.21	0.00	0.12	0.16	0.13	0.14	0.10	0.14	0.17
Cl	0.11	0.05	0.04	0.06	0.06	0.09	0.08	0.09	0.09	0.09	0.10	0.09	0.07	0.07
BaO	0.00	0.27	0.23	0.39	0.18	0.18	0.00	0.23	0.16	0.00	0.25	0.29	0.18	0.31
Total	90.53	90.90	93.07	94.35	92.33	93.41	90.10	92.12	91.39	91.39	92.85	92.81	92.14	93.66

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Si	2.95	2.95	3.00	2.95	2.97	2.93	2.82	2.93	2.92	2.98	2.97	2.95	2.98	2.96
Al iv	1.05	1.05	1.00	1.05	1.03	1.07	1.18	1.07	1.08	1.02	1.03	1.05	1.02	1.04
Al vi	0.79	0.76	0.80	0.81	0.78	0.82	0.72	0.87	0.81	0.81	0.83	0.80	0.82	0.80
Ti	0.11	0.08	0.10	0.11	0.10	0.10	0.09	0.08	0.08	0.10	0.09	0.09	0.10	0.10
Cr	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.01
Fe	1.11	1.17	1.03	1.09	1.08	1.07	1.24	1.12	1.17	1.09	1.06	1.09	1.06	1.08
Mn	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01
K	0.94	0.78	0.86	0.90	0.89	0.88	0.77	0.87	0.85	0.93	0.91	0.90	0.90	0.90
Mg	1.48	1.59	1.58	1.48	1.56	1.51	1.66	1.45	1.53	1.49	1.51	1.54	1.52	1.54
Ca	0.00	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Na	0.02	0.02	0.03	0.03	0.03	0.03	0.00	0.02	0.03	0.02	0.02	0.02	0.02	0.03
Cl	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.00	0.00
Ba	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.01	0.01	0.01	0.01
Fe/(Fe+Mg)	0.43	0.42	0.39	0.42	0.41	0.42	0.43	0.44	0.43	0.42	0.41	0.41	0.41	0.41

BLB97-003e Plagioclase

Sample	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P27
SiO ₂	60.03	59.44	59.11	57.78	57.26	57.98	59.90	60.78	60.18	60.30	58.00
Al ₂ O ₃	23.39	24.62	24.29	24.33	26.17	25.93	23.87	23.65	23.67	23.77	25.35
K ₂ O	0.07	0.04	0.05	0.06	0.05	0.04	0.13	0.08	0.09	0.09	0.02
CaO	5.22	5.96	6.20	6.29	7.67	6.36	5.19	5.35	5.33	5.51	7.17
Na ₂ O	8.44	8.09	8.08	7.89	7.14	7.74	8.54	8.56	8.69	8.65	7.60
FeO	0.03	0.02	0.07	0.48	0.34	0.16	0.00	0.01	0.04	0.07	0.21
SrO	0.14	0.06	0.09	0.10	0.12	0.10	0.13	0.17	0.08	0.05	0.13
BaO	0.00	0.12	0.01	0.13	0.04	0.00	0.04	0.02	0.02	0.00	0.01
Total	97.31	98.34	97.90	97.06	98.79	98.31	97.80	98.62	98.11	98.44	98.48

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.74	2.69	2.69	2.67	2.60	2.63	2.72	2.74	2.73	2.73	2.64
Al	1.26	1.31	1.30	1.32	1.40	1.39	1.28	1.26	1.26	1.27	1.36
K	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.00
Ca	0.26	0.29	0.30	0.31	0.37	0.31	0.25	0.26	0.26	0.27	0.35
Na	0.75	0.71	0.71	0.71	0.63	0.68	0.75	0.75	0.76	0.76	0.67
Fe	0.00	0.00	0.00	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.01
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
%Ab	74.2	70.9	70.0	69.2	62.5	68.6	74.3	74.0	74.3	73.6	65.7
%An	25.4	28.9	29.7	30.5	37.2	31.1	24.9	25.6	25.2	25.9	34.2
%Or	0.4	0.2	0.3	0.4	0.3	0.2	0.8	0.5	0.5	0.5	0.1

BLB97-003c Plagioclase (Continued)

Sample	P32	P33	P34	P40	P41	P42	P43	P44	P45	P60	P61
SiO ₂	60.00	62.00	62.08	61.64	59.79	61.41	61.00	60.92	61.06	59.91	60.43
Al ₂ O ₃	23.01	23.18	23.26	22.70	24.37	23.07	23.41	23.33	23.55	24.12	24.35
K ₂ O	0.09	0.06	0.06	0.08	0.06	0.10	0.07	0.12	0.06	1.04	0.06
CaO	4.90	4.57	4.70	4.13	5.76	4.56	4.81	4.66	5.18	5.58	5.90
Na ₂ O	8.80	9.00	9.09	9.11	8.50	9.15	8.98	9.11	8.82	7.72	8.29
FeO	0.08	0.04	0.05	0.02	0.02	0.05	0.06	0.05	0.07	0.25	0.18
SrO	0.09	0.08	0.10	0.06	0.14	0.18	0.04	0.11	0.15	0.13	0.03
BaO	0.00	0.07	0.04	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.17
Total	96.96	99.00	99.39	97.74	98.77	98.51	98.36	98.30	98.89	98.74	99.40

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.75	2.78	2.77	2.79	2.70	2.77	2.75	2.75	2.75	2.71	2.71
Al	1.24	1.22	1.22	1.21	1.30	1.23	1.24	1.24	1.25	1.29	1.29
K	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.06	0.00
Ca	0.24	0.22	0.22	0.20	0.28	0.22	0.23	0.23	0.25	0.27	0.28
Na	0.78	0.78	0.79	0.80	0.74	0.80	0.79	0.80	0.77	0.68	0.72
Fe	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
%Ab	76.1	77.8	77.5	79.6	72.5	77.9	76.9	77.4	75.2	67.2	71.5
%An	23.4	21.9	22.1	19.9	27.2	21.5	22.8	21.9	24.4	26.8	28.2
%Or	0.5	0.3	0.3	0.5	0.3	0.6	0.4	0.7	0.4	5.9	0.3

BLB97-003c Plagioclase (Continued)

Sample	P62	P63	P64	P69	P70	P71	P72	P73	P77	P78	P79
SiO ₂	59.81	60.48	60.38	60.38	61.70	62.59	61.97	61.48	57.14	57.67	61.65
Al ₂ O ₃	24.26	24.23	23.36	23.95	23.60	23.20	22.97	23.42	25.64	25.28	23.02
K ₂ O	0.06	0.07	0.96	0.05	0.06	0.09	0.07	0.06	5.08	1.74	0.07
CaO	5.86	5.94	4.67	5.53	4.93	4.52	4.53	4.68	3.51	5.40	4.32
Na ₂ O	8.35	8.26	8.19	8.48	8.97	9.04	9.10	8.97	5.34	6.83	9.02
FeO	0.05	0.11	0.43	0.25	0.11	0.08	0.21	0.24	0.96	0.75	0.03
SrO	0.12	0.09	0.12	0.04	0.09	0.10	0.12	0.07	0.13	0.12	0.11
BaO	0.00	0.14	0.14	0.00	0.27	0.11	0.00	0.00	0.00	0.01	0.21
Total	98.52	99.32	98.27	98.68	99.73	99.72	98.97	98.91	97.79	97.79	98.42

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.70	2.71	2.74	2.72	2.75	2.78	2.78	2.76	2.65	2.65	2.78
Al	1.29	1.28	1.25	1.27	1.24	1.22	1.21	1.24	1.40	1.37	1.22
K	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.30	0.10	0.00
Ca	0.28	0.29	0.23	0.27	0.24	0.22	0.22	0.22	0.17	0.27	0.21
Na	0.73	0.72	0.72	0.74	0.78	0.78	0.79	0.78	0.48	0.61	0.79
Fe	0.00	0.00	0.02	0.01	0.00	0.00	0.01	0.01	0.04	0.03	0.00
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Ab	71.8	71.3	71.8	73.3	76.4	78.0	78.1	77.4	50.3	62.3	78.8
% An	27.8	28.3	22.6	26.4	23.2	21.5	21.5	22.3	18.3	27.2	20.8
% Or	0.3	0.4	5.6	0.3	0.4	0.5	0.4	0.3	31.5	10.4	0.4

BLB97-003e Plagioclase (Continued)

Sample	P80	P81	P92	P93	P94	P95	P96	P101	P102	P103	P108
SiO ₂	60.64	59.13	58.86	60.69	60.00	59.42	59.51	60.05	60.38	59.89	60.19
Al ₂ O ₃	23.81	25.02	25.32	24.00	23.67	24.55	24.85	24.31	24.32	24.32	24.64
K ₂ O	0.07	0.09	2.76	0.05	0.08	0.04	0.07	0.06	0.09	0.05	0.07
CaO	5.40	6.58	2.54	5.44	5.34	6.31	6.32	5.94	5.87	5.82	5.89
Na ₂ O	8.39	7.88	7.04	8.66	8.65	8.06	8.00	8.41	8.33	8.36	8.36
FeO	0.22	0.42	0.89	0.17	0.14	0.03	0.04	0.08	0.13	0.08	0.25
SrO	0.08	0.12	0.06	0.12	0.08	0.09	0.04	0.18	0.13	0.11	0.05
BaO	0.02	0.10	0.24	0.03	0.03	0.00	0.00	0.00	0.00	0.21	0.00
Total	98.63	99.34	97.72	99.17	98.00	98.49	98.82	99.02	99.24	98.85	99.46

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.73	2.66	2.70	2.72	2.73	2.69	2.68	2.70	2.71	2.70	2.70
Al	1.26	1.33	1.37	1.27	1.27	1.31	1.32	1.29	1.29	1.29	1.30
K	0.00	0.01	0.16	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Ca	0.26	0.32	0.12	0.26	0.26	0.31	0.31	0.29	0.28	0.28	0.28
Na	0.73	0.69	0.63	0.75	0.76	0.71	0.70	0.73	0.72	0.73	0.73
Fe	0.01	0.02	0.03	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Ab	73.5	68.1	68.6	74.0	74.2	69.6	69.3	71.7	71.6	72.0	71.7
% An	26.1	31.4	13.7	25.7	25.3	30.1	30.3	28.0	27.9	27.7	27.9
% Or	0.4	0.5	17.7	0.3	0.4	0.2	0.4	0.3	0.5	0.3	0.4

BLB97-003e Plagioclase (Continued)

Sample	P109	P115	P116	P125	P130	P131	P136	P137	P138	P149	P150
SiO ₂	57.98	60.64	60.60	59.47	58.45	59.79	59.32	60.39	60.54	60.26	60.21
Al ₂ O ₃	23.68	23.60	24.37	25.17	24.58	25.23	24.22	23.81	24.00	23.97	23.77
K ₂ O	0.07	0.40	0.48	0.05	0.04	0.05	0.84	0.32	0.05	0.08	0.07
CaO	5.61	5.32	5.53	6.56	6.36	6.53	5.27	5.53	5.35	5.56	5.33
Na ₂ O	8.11	8.09	8.21	7.84	7.67	8.12	7.71	8.21	8.66	8.45	8.48
FeO	1.26	0.44	0.08	0.17	0.88	0.12	0.35	0.09	0.08	0.00	0.08
SiO	0.09	0.14	0.13	0.12	0.08	0.12	0.19	0.08	0.07	0.11	0.12
BaO	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.14	0.08	0.10	0.08
Total	96.81	98.70	99.40	99.38	98.06	99.96	97.90	98.56	98.84	98.54	98.15

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.68	2.74	2.72	2.67	2.67	2.67	2.71	2.73	2.72	2.72	2.73
Al	1.29	1.26	1.29	1.33	1.32	1.33	1.30	1.27	1.27	1.28	1.27
K	0.00	0.02	0.03	0.00	0.00	0.00	0.05	0.02	0.00	0.00	0.00
Ca	0.28	0.26	0.27	0.32	0.31	0.31	0.26	0.27	0.26	0.27	0.26
Na	0.73	0.71	0.71	0.68	0.68	0.70	0.68	0.72	0.76	0.74	0.75
Fe	0.05	0.02	0.00	0.01	0.03	0.00	0.01	0.00	0.00	0.00	0.00
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Ab	72.0	71.6	70.9	68.2	68.4	69.0	69.0	71.6	74.3	73.0	73.9
% An	27.6	26.1	26.4	31.5	31.4	30.7	26.1	26.6	25.4	26.5	25.7
% Or	0.4	2.3	2.7	0.3	0.2	0.3	4.9	1.8	0.3	0.4	0.4

BLB97-003e Plagioclase (Continued)

Sample	P151	P152	P153	P154	P161	P167	P175	P176	P177	P178	P183
SiO ₂	60.31	60.34	62.07	60.71	59.02	58.89	63.95	60.40	59.84	59.95	60.94
Al ₂ O ₃	24.10	24.16	23.01	23.68	25.49	24.74	22.90	24.14	23.80	24.49	24.23
K ₂ O	0.09	0.07	0.08	0.09	0.04	0.61	0.08	0.05	0.08	0.07	0.08
CaO	5.69	5.65	4.60	5.37	7.32	6.38	3.74	5.86	5.79	5.98	5.82
Na ₂ O	8.28	8.19	8.76	8.42	7.66	7.25	9.38	8.55	8.37	8.36	8.26
FeO	0.07	0.00	0.00	0.00	0.14	0.21	0.46	0.24	0.23	0.20	0.14
SrO	0.12	0.11	0.17	0.16	0.09	0.16	0.01	0.08	0.13	0.11	0.14
BaO	0.00	0.06	0.10	0.00	0.01	0.36	0.19	0.00	0.00	0.12	0.03
Total	98.65	98.57	98.78	98.43	99.78	98.61	100.69	99.32	98.25	99.28	99.65

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.72	2.72	2.79	2.74	2.65	2.68	2.81	2.71	2.72	2.70	2.72
Al	1.28	1.28	1.22	1.26	1.35	1.33	1.19	1.28	1.27	1.30	1.28
K	0.01	0.00	0.00	0.01	0.00	0.04	0.00	0.00	0.00	0.00	0.00
Ca	0.27	0.27	0.22	0.26	0.35	0.31	0.18	0.28	0.28	0.29	0.28
Na	0.72	0.72	0.76	0.74	0.67	0.64	0.80	0.74	0.74	0.73	0.72
Fe	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.01	0.01	0.01	0.01
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
%Ab	72.1	72.1	77.1	73.5	65.3	64.8	81.6	72.3	72.0	71.4	71.6
%An	27.4	27.5	22.4	25.9	34.5	31.6	18.0	27.4	27.5	28.2	27.9
%Or	0.5	0.4	0.5	0.5	0.2	3.6	0.4	0.3	0.5	0.4	0.5

BLB97-003e Plagioclase (Continued)

Sample	P184	P185	P186	P196	P198	P199	P200	P201	P202	P203	P204
SiO ₂	60.94	61.43	62.95	55.27	60.64	55.31	55.31	61.12	61.87	62.29	61.28
Al ₂ O ₃	23.86	23.00	23.09	22.52	23.79	24.74	24.67	23.68	23.41	23.20	23.16
K ₂ O	1.10	0.09	0.14	0.04	0.26	0.25	0.10	0.30	0.07	0.09	0.08
CaO	3.34	4.43	4.23	5.23	5.50	5.94	7.14	5.37	4.90	4.83	5.02
Na ₂ O	8.34	9.09	9.12	7.25	8.17	6.54	6.33	7.75	8.18	8.25	8.20
FeO	0.42	0.08	0.13	7.09	0.25	2.92	0.29	0.08	0.09	0.08	0.03
SrO	0.15	0.01	0.04	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00
BaO	0.00	0.20	0.00	0.08	0.07	0.00	0.00	0.00	0.00	0.04	0.00
Total	98.15	98.33	99.69	97.48	98.76	95.70	93.83	98.29	98.52	98.77	97.78

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.76	2.77	2.79	2.62	2.73	2.61	2.63	2.75	2.77	2.79	2.77
Al	1.27	1.22	1.21	1.26	1.26	1.37	1.38	1.26	1.24	1.22	1.23
K	0.06	0.01	0.01	0.00	0.01	0.02	0.01	0.02	0.00	0.00	0.00
Ca	0.16	0.21	0.20	0.27	0.27	0.30	0.36	0.26	0.24	0.23	0.24
Na	0.73	0.80	0.78	0.67	0.71	0.60	0.58	0.68	0.71	0.71	0.72
Fe	0.02	0.00	0.00	0.28	0.01	0.12	0.01	0.00	0.00	0.00	0.00
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Ab	76.4	78.4	79.0	71.3	71.8	65.5	61.2	71.0	74.8	75.1	74.4
% An	16.9	21.1	20.2	28.4	26.7	32.8	38.1	27.2	24.8	24.3	25.2
% Or	6.6	0.5	0.8	0.3	1.5	1.7	0.6	1.8	0.4	0.5	0.5

BLB97-003e Plagioclase (Continued)

Sample	P205	P206	P207	P208	P209	P210	P211	P213	P214	P215	P216
SiO ₂	62.13	60.27	61.14	60.79	60.91	60.10	61.06	61.50	60.38	60.78	61.39
Al ₂ O ₃	22.83	25.65	23.63	23.91	23.71	24.16	23.48	23.28	24.34	24.06	23.53
K ₂ O	0.07	0.06	0.08	0.07	0.08	0.17	0.05	0.17	0.06	0.06	0.10
CaO	4.69	4.71	5.53	5.76	5.48	5.75	5.08	4.80	5.79	5.91	5.32
Na ₂ O	8.40	7.66	7.87	7.77	7.75	7.54	8.18	8.28	7.70	7.77	8.02
FeO	0.20	0.12	0.10	0.07	0.20	0.05	0.04	0.11	0.09	0.09	0.02
SrO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BaO	0.15	0.13	0.02	0.00	0.02	0.03	0.00	0.10	0.00	0.00	0.01
Total	98.46	98.60	98.38	98.37	98.15	97.80	97.89	98.23	98.35	98.66	98.39

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.79	2.70	2.75	2.74	2.75	2.72	2.76	2.77	2.72	2.73	2.76
Al	1.21	1.35	1.25	1.27	1.26	1.29	1.25	1.24	1.29	1.27	1.25
K	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.01
Ca	0.23	0.23	0.27	0.28	0.26	0.28	0.25	0.23	0.28	0.28	0.26
Na	0.73	0.67	0.69	0.68	0.68	0.66	0.72	0.72	0.67	0.68	0.70
Fe	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
%Ab	76.1	74.4	71.7	70.7	71.6	69.6	74.3	75.0	70.4	70.1	72.8
%An	23.5	25.3	27.8	28.9	28.0	29.3	25.5	24.0	29.2	29.5	26.6
%Or	0.4	0.4	0.5	0.4	0.5	1.1	0.3	1.0	0.4	0.4	0.6

BLB97-003e Plagioclase (Continued)

Sample	P217	P218	P219	P220	P221	P222	P223	P224	P225	P226	P227
SiO ₂	61.37	60.63	60.46	60.46	59.84	59.31	60.54	59.63	63.03	60.88	62.04
Al ₂ O ₃	23.73	24.21	24.20	24.37	24.41	24.74	24.23	24.21	22.40	23.68	23.16
K ₂ O	0.07	0.09	0.05	0.06	0.05	0.07	0.05	0.59	0.10	0.06	0.04
CaO	5.40	5.87	6.09	6.34	6.32	6.62	5.91	5.82	4.05	5.45	4.86
Na ₂ O	7.97	7.73	7.61	7.48	7.51	7.27	7.71	7.42	8.81	7.92	8.29
FeO	0.03	0.20	0.16	0.15	0.10	0.09	0.06	0.01	0.00	0.04	0.01
SrO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BaO	0.00	0.13	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.09	0.00
Total	98.58	98.85	98.57	98.86	98.23	98.19	98.49	97.67	98.39	98.12	98.40

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.75	2.72	2.72	2.71	2.70	2.69	2.72	2.71	2.82	2.75	2.78
Al	1.26	1.28	1.28	1.29	1.30	1.32	1.28	1.30	1.18	1.26	1.22
K	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.03	0.01	0.00	0.00
Ca	0.26	0.28	0.29	0.30	0.31	0.32	0.28	0.28	0.19	0.26	0.23
Na	0.69	0.67	0.66	0.65	0.66	0.64	0.67	0.65	0.77	0.69	0.72
Fe	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Ab	72.4	70.0	69.1	67.8	68.1	66.2	70.0	67.3	79.3	72.2	75.3
% An	27.1	29.4	30.6	31.8	31.6	33.4	29.7	29.2	20.1	27.5	24.4
% Or	0.4	0.6	0.3	0.4	0.3	0.4	0.3	3.5	0.6	0.4	0.3

BLB97-003c Plagioclase (Continued)

Sample	P228	P229	P231	P232	P233	P234	P235	P236	P237	P238	P239
SiO ₂	60.38	60.50	61.29	60.75	60.91	61.05	61.01	60.64	61.92	62.05	55.64
Al ₂ O ₃	24.18	24.12	23.57	23.90	23.73	23.73	23.40	23.60	22.96	22.75	20.75
K ₂ O	0.06	0.07	0.07	0.10	0.08	0.04	0.05	0.07	0.07	0.08	0.04
CaO	5.87	5.90	5.52	5.60	5.51	5.60	5.18	5.44	4.55	4.30	5.29
Na ₂ O	7.67	7.66	8.01	7.91	7.87	8.06	8.15	8.05	8.46	8.63	8.50
FeO	0.08	0.03	0.00	0.05	0.11	0.09	0.04	0.03	0.07	0.00	0.07
SrO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BaO	0.00	0.00	0.02	0.11	0.10	0.05	0.00	0.11	0.00	0.03	0.01
Total	98.25	98.27	98.48	98.42	98.31	98.63	97.83	97.94	98.03	97.84	90.30

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.72	2.73	2.76	2.74	2.75	2.74	2.76	2.75	2.79	2.80	2.75
Al	1.29	1.28	1.25	1.27	1.26	1.26	1.25	1.26	1.22	1.21	1.21
K	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ca	0.28	0.29	0.27	0.27	0.27	0.27	0.25	0.26	0.22	0.21	0.28
Na	0.67	0.67	0.70	0.69	0.69	0.70	0.71	0.71	0.74	0.75	0.81
Fe	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
%Ab	70.0	69.9	72.1	71.5	71.7	72.1	73.8	72.5	76.8	78.0	74.2
%An	29.6	29.8	27.5	28.0	27.8	27.7	25.9	27.1	22.8	21.5	25.6
%Or	0.4	0.4	0.4	0.6	0.5	0.3	0.3	0.4	0.4	0.5	0.2

BLB97-003c Plagioclase (Continued)

Sample	P240	P241	P242	P243	P244	P245	P246	P247	P248	P249	P250
SiO ₂	55.08	60.76	60.88	59.85	60.35	60.23	60.98	61.36	61.13	61.95	60.81
Al ₂ O ₃	21.16	23.80	23.52	24.15	24.34	24.18	24.03	23.86	23.80	22.79	23.36
K ₂ O	0.08	0.07	0.22	0.13	0.05	0.09	0.03	0.06	0.05	0.69	0.05
CaO	5.46	5.62	5.27	6.15	6.27	5.96	5.64	5.14	5.31	3.39	5.45
Na ₂ O	8.24	7.91	7.97	7.55	7.57	7.82	7.92	8.16	8.02	7.99	7.97
FeO	0.04	0.00	0.00	0.11	0.05	0.00	0.10	0.05	0.04	0.20	0.05
SrO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BaO	0.11	0.00	0.07	0.04	0.14	0.14	0.05	0.00	0.13	0.21	0.00
Total	90.16	98.16	97.94	97.98	98.77	98.41	98.76	98.64	98.47	97.22	97.68

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.73	2.74	2.75	2.71	2.71	2.72	2.74	2.75	2.75	2.81	2.76
Al	1.24	1.27	1.25	1.29	1.29	1.29	1.27	1.26	1.26	1.22	1.25
K	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.04	0.00
Ca	0.29	0.27	0.26	0.30	0.30	0.29	0.27	0.25	0.26	0.16	0.26
Na	0.79	0.69	0.70	0.66	0.66	0.68	0.69	0.71	0.70	0.70	0.70
Fe	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Ab	72.9	71.5	72.3	68.4	68.4	70.0	71.6	73.9	73.0	77.5	72.4
% An	26.7	28.1	26.4	30.8	31.3	29.5	28.2	25.7	26.7	18.1	27.3
% Or	0.5	0.4	1.3	0.8	0.3	0.5	0.2	0.3	0.3	4.4	0.3

BLB97-003e Plagioclase (Continued)

Sample	P251	P252	P253	P254	P255	P256	P257	P258	P259
SiO ₂	60.55	60.54	61.51	60.30	61.05	60.69	60.35	60.76	62.62
Al ₂ O ₃	23.64	23.57	23.33	23.79	23.61	23.89	23.77	24.22	22.69
K ₂ O	0.05	0.06	0.07	0.08	0.04	0.06	0.04	0.05	0.07
CaO	5.56	5.47	5.26	5.74	5.34	5.65	5.59	6.07	4.31
Na ₂ O	7.88	7.97	8.15	7.87	7.97	8.04	7.87	7.66	8.60
FeO	0.11	0.01	0.02	0.01	0.05	0.17	0.09	0.08	0.01
SrO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BaO	0.00	0.01	0.00	0.05	0.00	0.11	0.00	0.07	0.00
Total	97.79	97.62	98.35	97.84	98.07	98.60	97.70	98.91	98.29

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8
Si	2.74	2.75	2.77	2.73	2.75	2.73	2.74	2.73	2.81
Al	1.26	1.26	1.24	1.27	1.26	1.27	1.27	1.28	1.20
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ca	0.27	0.27	0.25	0.28	0.26	0.27	0.27	0.29	0.21
Na	0.69	0.70	0.71	0.69	0.70	0.70	0.69	0.67	0.75
Fe	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
%Ab	71.7	72.2	73.4	71.0	72.8	71.8	71.6	69.3	78.0
%An	28.0	27.4	26.2	28.6	27.0	27.9	28.1	30.4	21.6
%Or	0.3	0.4	0.4	0.5	0.3	0.4	0.2	0.3	0.4

Sheet4

SAMPLE	M1	M2	M3	M4	M5	M6	M7	M8
NA2O	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00
K2O	0.02	0.02	0.01	0.00	0.01	0.00	0.01	0.00
FEO	18.34	17.86	17.86	18.27	17.95	17.82	17.37	18.19
MGO	18.53	18.97	18.54	18.78	19.00	19.23	18.55	18.67
AL2O3	22.70	22.37	22.58	23.12	23.36	23.10	22.41	22.61
SIO2	23.66	24.46	24.51	24.50	24.66	24.19	23.83	23.84
CAO	0.01	0.04	0.07	0.03	0.03	0.01	0.00	0.03
TIO2	0.10	0.11	0.11	0.10	0.08	0.10	0.06	0.10
CR2O3	0.06	0.07	0.00	0.06	0.05	0.08	0.04	0.06
MNO	0.12	0.15	0.12	0.12	0.13	0.14	0.09	0.11
NIO	0.05	0.14	0.00	0.03	0.05	0.15	0.12	0.05
F	0.13	0.24	0.23	0.17	0.11	0.38	0.12	0.00
CL	0.00	0.04	0.00	0.00	0.02	0.06	0.02	0.01
RB2O	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00
SRO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BAO	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.26
ZNO	0.19	0.10	0.10	0.00	0.04	0.09	0.00	0.11
V2O3	0.08	0.01	0.00	0.02	0.07	0.06	0.03	0.10
P2O5	0.05	0.02	0.00	0.01	0.02	0.11	0.00	0.00
TOTAL	84.03	84.61	84.20	85.23	85.61	85.54	82.67	84.14

MT98-101 Garnet

Sample	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11
SiO ₂	36.09	36.43	36.54	36.49	35.00	35.99	36.02	36.19	36.02	36.27	35.84
Al ₂ O ₃	21.01	21.07	21.09	21.35	20.20	20.92	21.13	21.08	20.85	21.06	20.68
TiO ₂	0.07	0.08	0.09	0.10	0.14	0.07	0.11	0.12	0.16	0.14	0.13
Cr ₂ O ₃	0.08	0.02	0.07	0.03	0.02	0.04	0.01	0.03	0.07	0.01	0.08
FeO	30.48	31.52	30.62	30.40	29.99	30.64	29.64	30.13	28.72	29.07	28.75
MnO	0.45	0.56	0.77	1.30	2.15	2.38	2.98	3.35	3.54	3.42	3.55
MgO	3.24	3.31	3.05	2.97	2.62	2.74	2.55	2.39	2.29	2.37	2.21
CaO	6.99	6.31	6.87	6.72	6.29	6.13	6.30	6.07	6.82	6.70	6.92
Na ₂ O	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
K ₂ O	0.02	0.01	0.00	0.02	0.02	0.00	0.00	0.00	0.00	0.02	0.00
Total	98.43	99.30	99.10	99.38	96.43	98.93	98.73	99.35	98.48	99.05	98.17

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	2.93	2.94	2.95	2.94	2.93	2.93	2.93	2.94	2.94	2.94	2.94
Al iv	0.07	0.06	0.05	0.06	0.07	0.07	0.07	0.06	0.06	0.06	0.06
Al vi	1.94	1.94	1.95	1.96	1.92	1.94	1.96	1.95	1.95	1.96	1.94
Ti	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01
Cr	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Fe	2.07	2.13	2.07	2.05	2.10	2.09	2.02	2.04	1.96	1.97	1.97
Mn	0.03	0.04	0.05	0.09	0.15	0.16	0.21	0.23	0.24	0.24	0.25
Mg	0.39	0.40	0.37	0.36	0.33	0.33	0.31	0.29	0.28	0.29	0.27
Ca	0.61	0.55	0.59	0.58	0.56	0.53	0.55	0.53	0.60	0.58	0.61
Na	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Alm	66.7	68.4	67.1	66.6	66.8	66.9	65.5	66.1	63.6	64.1	63.7
% Sp	1.0	1.2	1.7	3.0	5.1	5.6	7.1	8.0	8.6	8.3	8.6
% Py	14.5	14.7	13.5	13.1	11.6	12.0	11.2	10.3	10.0	10.3	9.6
% Gr	24.4	21.3	23.9	23.3	21.9	20.7	21.7	20.6	24.0	23.4	24.4

MT98-101 Garnet (continued)

Sample	G12	G13	G14	G15	G16	G17	G18	G19	G35	G36	G37
SiO ₂	36.38	36.47	36.57	36.45	36.27	36.55	36.44	36.11	36.55	36.22	36.26
Al ₂ O ₃	21.06	21.21	20.92	21.00	21.15	21.19	21.06	20.93	21.02	20.96	20.96
TiO ₂	0.09	0.10	0.06	0.08	0.09	0.10	0.08	0.10	0.12	0.16	0.08
Cr ₂ O ₃	0.00	0.05	0.04	0.03	0.02	0.12	0.02	0.03	0.11	0.00	0.01
FeO	29.59	29.18	30.31	28.88	30.65	31.46	31.11	30.92	31.08	30.71	30.51
MnO	3.76	3.19	3.13	3.27	0.70	0.56	0.39	0.38	0.43	0.49	0.42
MgO	2.43	2.93	2.63	2.45	2.98	3.12	3.17	3.21	3.20	3.18	3.33
CaO	6.07	6.01	5.45	6.82	6.83	6.17	6.60	6.90	6.40	6.83	6.78
Na ₂ O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
K ₂ O	0.00	0.01	0.00	0.00	0.00	0.02	0.03	0.01	0.01	0.00	0.00
Total	99.37	99.15	99.11	98.97	98.69	99.28	98.90	98.60	98.91	98.55	98.37

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	2.95	2.95	2.96	2.95	2.94	2.95	2.95	2.93	2.95	2.94	2.94
Al iv	0.05	0.05	0.04	0.05	0.06	0.05	0.05	0.07	0.05	0.06	0.06
Al vi	1.96	1.97	1.96	1.96	1.96	1.96	1.95	1.94	1.95	1.94	1.95
Ti	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.01	0.01	0.01	0.01
Cr	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00
Fe	2.00	1.97	2.05	1.96	2.08	2.12	2.10	2.10	2.10	2.08	2.07
Mn	0.26	0.22	0.21	0.22	0.05	0.04	0.03	0.03	0.03	0.03	0.03
Mg	0.29	0.35	0.32	0.30	0.36	0.37	0.38	0.39	0.38	0.39	0.40
Ca	0.53	0.52	0.47	0.59	0.59	0.53	0.57	0.60	0.55	0.59	0.59
Na	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Alm	65.0	64.4	67.1	63.8	67.5	69.2	68.2	67.4	68.5	67.3	67.0
% Sp	9.1	7.7	7.6	7.9	1.6	1.3	0.9	0.8	1.0	1.1	0.9
% Py	10.5	13.0	11.6	10.7	13.2	13.9	14.1	14.3	14.4	14.2	15.0
% Gr	20.6	20.5	18.3	23.9	23.9	21.0	22.8	23.9	22.0	23.7	23.6

MT98-101 Garnet (continued)

Sample	G42	G43	G50	G51	G52	G53	G54	G55	G56	G57	G58
SiO ₂	36.46	35.78	36.24	36.45	36.32	36.54	36.51	36.82	36.20	36.40	36.14
Al ₂ O ₃	20.98	20.68	20.94	21.11	21.08	20.94	21.04	21.15	20.90	20.99	20.90
TiO ₂	0.07	0.10	0.06	0.07	0.11	0.12	0.12	0.09	0.10	0.12	0.13
Cr ₂ O ₃	0.07	0.02	0.02	0.00	0.02	0.00	0.01	0.00	0.07	0.00	0.06
FeO	31.05	28.62	29.16	30.70	29.80	29.10	29.59	28.85	28.82	29.23	29.00
MnO	0.55	3.42	3.50	2.57	2.87	3.26	3.53	3.39	3.41	3.47	3.66
MgO	3.23	2.30	2.56	2.68	2.55	2.48	2.41	2.36	2.29	2.30	2.34
CaO	6.54	6.47	5.80	5.63	6.31	6.27	6.55	6.89	6.84	6.52	6.09
Na ₂ O	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00
K ₂ O	0.01	0.02	0.00	0.04	0.02	0.01	0.03	0.00	0.00	0.01	0.00
Total	98.96	97.41	98.28	99.25	99.08	98.73	99.79	99.55	98.64	99.04	98.32

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	2.95	2.95	2.96	2.95	2.94	2.97	2.95	2.96	2.95	2.95	2.95
Al iv	0.05	0.05	0.04	0.05	0.06	0.03	0.05	0.04	0.05	0.05	0.05
Al vi	1.95	1.96	1.97	1.97	1.96	1.97	1.95	1.97	1.95	1.96	1.97
Ti	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe	2.10	1.97	1.99	2.08	2.02	1.98	2.00	1.94	1.96	1.98	1.98
Mn	0.04	0.24	0.24	0.18	0.20	0.22	0.24	0.23	0.24	0.24	0.25
Mg	0.39	0.28	0.31	0.32	0.31	0.30	0.29	0.28	0.28	0.28	0.29
Ca	0.57	0.57	0.51	0.49	0.55	0.55	0.57	0.59	0.60	0.57	0.53
Na	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Alm	67.9	64.3	65.2	67.8	65.7	64.9	64.6	63.7	63.9	64.7	64.9
% Sp	1.2	8.4	8.6	6.1	6.9	7.9	8.5	8.2	8.3	8.4	9.0
% Py	14.4	10.2	11.4	11.8	11.1	10.9	10.3	10.2	10.0	10.0	10.3
% Gr	22.4	22.9	20.0	18.9	21.7	21.8	22.4	24.2	24.1	22.7	21.1

MT98-101 Garnet (continued)

Sample	G59	G60	G61	G62	G63	G64	G79	G80	G81	G82	G106
SiO ₂	36.44	36.44	36.40	35.88	36.07	36.08	35.99	35.82	36.18	36.05	36.65
Al ₂ O ₃	20.82	20.97	20.89	20.63	20.77	20.78	20.66	20.65	20.96	20.72	21.33
TiO ₂	0.11	0.10	0.12	0.08	0.05	0.08	0.09	0.12	0.08	0.11	0.09
Cr ₂ O ₃	0.00	0.01	0.05	0.00	0.00	0.02	0.00	0.03	0.00	0.01	0.03
FeO	29.57	29.12	29.81	29.73	29.59	28.69	28.71	28.89	29.18	29.44	29.75
MnO	3.63	3.47	2.66	3.04	3.06	4.02	4.08	3.91	2.91	3.02	0.25
MgO	2.37	2.44	2.67	2.45	2.54	2.30	2.32	2.49	2.49	2.44	4.14
CaO	6.19	6.33	6.02	6.10	6.27	6.27	6.12	5.98	6.06	6.04	6.10
Na ₂ O	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K ₂ O	0.02	0.03	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.03
Total	99.16	98.93	98.66	97.92	98.35	98.23	97.97	97.90	97.86	97.84	98.35

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	2.96	2.96	2.96	2.95	2.95	2.95	2.96	2.95	2.96	2.96	2.95
Al iv	0.04	0.04	0.04	0.05	0.05	0.05	0.04	0.05	0.04	0.04	0.05
Al vi	1.95	1.96	1.96	1.95	1.95	1.96	1.96	1.95	1.98	1.96	1.98
Ti	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.01
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe	2.01	1.98	2.03	2.04	2.02	1.96	1.97	1.99	2.00	2.02	2.00
Mn	0.25	0.24	0.18	0.21	0.21	0.28	0.28	0.27	0.20	0.21	0.02
Mg	0.29	0.30	0.32	0.30	0.31	0.28	0.28	0.31	0.30	0.30	0.50
Ca	0.54	0.55	0.52	0.54	0.55	0.55	0.54	0.53	0.53	0.53	0.53
Na	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Alm	65.1	64.6	66.3	66.1	65.4	63.9	64.1	64.3	65.8	66.0	65.8
% Sp	8.8	8.5	6.4	7.4	7.3	10.0	10.2	9.7	7.1	7.4	0.6
% Py	10.3	10.7	11.8	10.7	11.1	10.0	10.2	11.0	11.1	10.8	19.5
% Gr	21.2	21.9	20.7	21.0	21.6	21.8	21.2	20.5	21.2	21.0	20.9

MT98-101 Garnet (continued)

Sample	G107	G108	G113	G114	G119	G120	G143	G144	G145	G146	G147
SiO ₂	37.14	36.74	37.12	36.63	37.01	36.41	36.65	36.85	36.11	37.32	37.28
Al ₂ O ₃	21.22	21.11	21.20	21.14	21.20	21.14	20.88	21.18	20.77	20.99	21.31
TiO ₂	0.05	0.07	0.00	0.07	0.08	0.05	0.06	0.16	0.08	0.08	0.09
Cr ₂ O ₃	0.07	0.00	0.04	0.04	0.00	0.00	0.05	0.03	0.02	0.04	0.05
FeO	30.38	29.77	30.47	29.56	30.09	29.87	30.40	30.87	30.70	30.07	30.25
MnO	0.35	2.20	0.30	2.20	0.34	2.74	0.36	0.38	0.49	0.62	0.61
MgO	3.96	3.03	4.16	2.97	4.03	2.91	3.48	3.53	3.54	3.15	3.15
CaO	6.20	6.03	6.00	6.12	6.11	6.05	6.92	6.76	6.44	6.56	6.68
Na ₂ O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
K ₂ O	0.03	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00
Total	99.41	98.94	99.30	98.74	98.87	99.16	98.80	99.76	98.15	98.84	99.42

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	2.97	2.97	2.97	2.96	2.97	2.94	2.96	2.95	2.94	3.00	2.98
Al iv	0.03	0.03	0.03	0.04	0.03	0.06	0.04	0.05	0.06	0.00	0.02
Al vi	1.96	1.97	1.96	1.98	1.97	1.96	1.94	1.94	1.93	1.99	1.99
Ti	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.00	0.01
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe	2.03	2.01	2.04	2.00	2.02	2.02	2.05	2.06	2.09	2.02	2.02
Mn	0.02	0.15	0.02	0.15	0.02	0.19	0.02	0.03	0.03	0.04	0.04
Mg	0.47	0.36	0.50	0.36	0.48	0.35	0.42	0.42	0.43	0.38	0.38
Ca	0.53	0.52	0.51	0.53	0.52	0.52	0.60	0.58	0.56	0.56	0.57
Na	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Alm	66.4	66.0	66.4	65.8	66.2	65.5	66.3	66.8	67.1	67.2	67.2
% Sp	0.8	5.2	0.7	5.2	0.8	6.5	0.8	0.9	1.1	1.4	1.4
% Py	18.3	13.6	19.3	13.4	18.8	12.8	15.7	15.8	16.0	14.4	14.2
% Gr	21.0	20.6	20.1	21.2	20.8	20.5	24.0	23.1	22.0	23.1	23.5

MT98-101 Garnet (continued)

Sample	G148	G149	G150	G151	G152	G153	G154	G155	G156	G157	G158
SiO ₂	37.21	37.05	36.87	37.21	37.31	37.17	36.51	36.87	37.19	36.90	36.79
Al ₂ O ₃	21.08	20.96	21.12	21.35	21.41	21.16	20.90	21.18	20.98	21.05	21.15
TiO ₂	0.10	0.09	0.22	0.12	0.08	0.07	0.12	0.09	0.11	0.14	0.12
Cr ₂ O ₃	0.00	0.07	0.01	0.05	0.06	0.01	0.03	0.04	0.06	0.01	0.05
FeO	30.84	30.84	30.70	30.59	29.99	30.64	30.40	31.08	30.32	30.36	30.54
MnO	0.49	0.47	0.52	0.47	0.44	0.61	0.54	0.57	0.50	0.41	0.33
MgO	3.30	3.23	3.35	3.29	3.24	3.18	3.09	3.13	3.28	3.24	3.31
CaO	6.03	6.25	6.09	6.35	6.55	6.66	6.97	6.32	6.59	6.38	6.58
Na ₂ O	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.02	0.00	0.00	0.00
K ₂ O	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.00	0.01
Total	99.06	98.96	98.87	99.43	99.08	99.52	98.58	99.30	99.03	98.48	98.88

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	2.99	2.98	2.97	2.98	2.99	2.98	2.96	2.96	2.99	2.98	2.96
Al iv	0.01	0.02	0.03	0.02	0.01	0.02	0.04	0.04	0.01	0.02	0.04
Al vi	1.98	1.97	1.97	1.99	2.00	1.97	1.95	1.97	1.97	1.98	1.97
Ti	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.01
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe	2.07	2.08	2.07	2.05	2.01	2.05	2.06	2.09	2.04	2.05	2.06
Mn	0.03	0.03	0.04	0.03	0.03	0.04	0.04	0.04	0.03	0.03	0.02
Mg	0.40	0.39	0.40	0.39	0.39	0.38	0.37	0.37	0.39	0.39	0.40
Ca	0.52	0.54	0.52	0.54	0.56	0.57	0.60	0.54	0.57	0.55	0.57
Na	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Alm	68.6	68.4	68.2	67.9	67.3	67.4	67.0	68.6	67.2	67.9	67.5
% Sp	1.1	1.1	1.2	1.1	1.0	1.4	1.2	1.3	1.1	0.9	0.7
% Py	15.1	14.7	15.3	15.0	14.9	14.3	13.8	14.0	14.9	14.8	15.0
% Gr	20.7	21.6	21.0	22.0	23.2	23.1	24.5	21.7	23.0	22.4	22.9

MT98-101 Garnet (continued)

Sample	G159	G160	G161	G162	G163	G164	G165	G166	G167	G168	G169
SiO ₂	36.96	36.97	36.86	37.06	36.90	36.89	37.00	37.01	36.74	37.21	36.94
Al ₂ O ₃	21.12	21.04	20.93	20.86	21.10	21.20	21.01	21.14	21.07	21.11	20.86
TiO ₂	0.12	0.10	0.05	0.07	0.06	0.06	0.07	0.09	0.10	0.06	0.13
Cr ₂ O ₃	0.03	0.00	0.01	0.02	0.05	0.07	0.00	0.02	0.04	0.00	0.00
FeO	29.91	30.92	31.02	30.64	29.45	29.95	29.81	29.34	29.54	29.39	30.03
MnO	0.35	0.30	0.34	0.34	2.77	2.76	2.68	2.57	2.45	2.36	2.30
MgO	3.25	3.43	3.53	3.53	2.57	2.57	2.62	2.45	2.55	2.53	2.58
CaO	7.06	6.31	6.03	6.53	5.96	5.71	6.03	6.38	6.00	6.20	6.20
Na ₂ O	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.03
K ₂ O	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.01	0.01	0.00	0.01
Total	98.80	99.08	98.80	99.07	98.86	99.23	99.22	99.00	98.51	98.84	99.07

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	2.97	2.97	2.97	2.98	2.98	2.98	2.98	2.99	2.98	3.00	2.98
Al iv	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.01	0.02	0.00	0.02
Al vi	1.97	1.97	1.96	1.95	1.99	1.99	1.98	2.00	1.99	2.01	1.97
Ti	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.01
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe	2.01	2.08	2.09	2.06	1.99	2.02	2.01	1.98	2.00	1.98	2.03
Mn	0.02	0.02	0.02	0.02	0.19	0.19	0.18	0.18	0.17	0.16	0.16
Mg	0.39	0.41	0.42	0.42	0.31	0.31	0.32	0.29	0.31	0.30	0.31
Ca	0.61	0.54	0.52	0.56	0.52	0.49	0.52	0.55	0.52	0.54	0.54
Na	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Alm	66.3	68.1	68.3	67.1	66.2	67.1	66.4	66.0	66.7	66.5	66.9
% Sp	0.8	0.7	0.8	0.8	6.7	6.7	6.4	6.2	6.0	5.7	5.5
% Py	14.7	15.5	16.1	16.0	11.5	11.4	11.6	10.9	11.5	11.3	11.4
% Gr	25.1	21.6	20.5	22.5	20.7	19.6	20.8	22.5	21.0	21.9	21.5

MT98-101 Garnet (continued)

Sample	G170	G171	G172	G173	G174	G175	G176	G177	G178	G179	G180
SiO ₂	36.91	36.98	36.93	36.88	37.00	36.92	36.73	37.11	36.91	36.72	37.09
Al ₂ O ₃	20.94	20.83	20.93	20.85	20.90	20.93	20.95	21.16	20.90	20.99	20.84
TiO ₂	0.12	0.12	0.09	0.15	0.15	0.13	0.16	0.13	0.11	0.10	0.10
Cr ₂ O ₃	0.00	0.07	0.00	0.00	0.03	0.03	0.06	0.00	0.14	0.00	0.03
FeO	29.69	29.63	29.52	28.69	28.45	29.11	28.80	29.01	29.04	29.63	29.66
MnO	2.18	2.49	3.81	3.54	3.35	3.56	3.34	3.07	3.03	2.88	2.67
MgO	2.72	2.64	2.48	2.42	2.41	2.47	2.43	2.43	2.54	2.74	2.67
CaO	6.12	5.97	5.07	6.19	6.26	6.14	6.30	6.33	5.97	6.02	5.94
Na ₂ O	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.02	0.00
K ₂ O	0.01	0.00	0.03	0.00	0.01	0.00	0.02	0.00	0.01	0.00	0.02
Total	98.68	98.74	98.86	98.71	98.55	99.30	98.80	99.25	98.65	99.11	99.02

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	2.99	2.99	2.99	2.99	3.00	2.98	2.98	2.99	2.99	2.97	2.99
Al iv	0.01	0.01	0.01	0.01	0.00	0.02	0.02	0.01	0.01	0.03	0.01
Al vi	1.98	1.98	1.99	1.98	1.99	1.97	1.98	1.99	1.99	1.97	1.98
Ti	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Fe	2.01	2.01	2.00	1.94	1.93	1.96	1.95	1.95	1.97	2.00	2.00
Mn	0.15	0.17	0.26	0.24	0.23	0.24	0.23	0.21	0.21	0.20	0.18
Mg	0.33	0.32	0.30	0.29	0.29	0.30	0.29	0.29	0.31	0.33	0.32
Ca	0.53	0.52	0.44	0.54	0.54	0.53	0.55	0.55	0.52	0.52	0.51
Na	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Alm	66.6	66.6	66.6	64.4	64.4	64.7	64.6	65.1	65.6	65.6	66.3
% Sp	5.2	6.0	9.6	8.7	8.3	8.7	8.2	7.5	7.4	6.9	6.4
% Py	12.2	11.8	11.1	10.7	10.8	10.9	10.7	10.8	11.4	12.1	11.9
% Gr	21.3	20.8	17.2	21.7	22.2	21.2	22.1	22.3	20.9	20.6	20.5

MT98-101 Garnet (continued)

Sample	G181	G182
SiO ₂	37.06	37.19
Al ₂ O ₃	21.21	21.33
TiO ₂	0.09	0.14
Cr ₂ O ₃	0.00	0.03
FeO	29.45	29.47
MnO	2.69	2.50
MgO	2.68	2.83
CaO	6.15	5.96
Na ₂ O	0.00	0.00
K ₂ O	0.00	0.01
Total	99.32	99.47

Number of cations in formula based on n oxygens

n	12	12
Si	2.98	2.98
Al iv	0.02	0.02
Al vi	1.99	2.00
Ti	0.01	0.01
Cr	0.00	0.00
Fe	1.98	1.98
Mn	0.18	0.17
Mg	0.32	0.34
Ca	0.53	0.51
Na	0.00	0.00
K	0.00	0.00
% Alm	65.7	66.0
% Sp	6.5	6.0
% Py	11.9	12.7
% Gr	21.3	20.6

BLB97-101 Plagioclase

Sample	P1	P2	P3	P31	P32	P38	P39	P40	P65	P67	P77
SiO ₂	62.17	63.56	62.30	62.39	63.50	59.41	60.56	51.59	49.97	58.32	58.61
Al ₂ O ₃	22.71	22.20	22.70	22.48	22.01	23.94	22.81	30.11	21.33	23.82	24.76
K ₂ O	0.06	0.07	0.08	0.07	0.06	0.20	3.04	4.46	0.17	0.12	0.15
CaO	3.99	3.33	4.20	3.87	3.20	5.37	4.21	2.59	4.97	5.60	6.72
Na ₂ O	9.22	9.81	9.03	9.48	9.81	8.67	7.38	4.72	7.04	8.46	7.82
FeO	0.06	0.15	0.11	0.17	0.07	0.60	0.53	0.57	8.38	0.64	0.15
SrO	0.05	0.08	0.10	0.10	0.07	0.07	0.11	0.11	0.02	0.09	0.08
BaO	0.05	0.14	0.00	0.00	0.05	0.16	0.02	0.32	0.13	0.00	0
Total	98.31	99.34	98.52	98.55	98.76	98.43	98.65	94.49	92.01	97.06	98.28

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.80	2.83	2.80	2.80	2.84	2.70	2.76	2.47	2.55	2.69	2.66
Al	1.20	1.17	1.20	1.19	1.16	1.28	1.23	1.70	1.28	1.29	1.33
K	0.00	0.00	0.00	0.00	0.00	0.01	0.18	0.27	0.01	0.01	0.01
Ca	0.19	0.16	0.20	0.19	0.15	0.26	0.21	0.13	0.27	0.28	0.33
Na	0.80	0.85	0.79	0.83	0.85	0.76	0.65	0.44	0.70	0.76	0.69
Fe	0.00	0.01	0.00	0.01	0.00	0.02	0.02	0.02	0.36	0.02	0.01
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
% Ab	80.4	83.9	79.2	81.3	84.4	73.7	63.0	51.9	71.1	72.7	67.2
% An	19.2	15.7	20.4	18.3	15.2	25.2	19.9	15.8	27.7	26.6	31.9
% Or	0.3	0.4	0.5	0.4	0.3	1.1	17.1	32.3	1.1	0.7	0.8

BLB97-101 Plagioclase (Continued)

Sample	P78	P83	P84	P91	P92	P93	P94	P95	P96	P109	P110
SiO ₂	58.73	60.19	59.00	62.12	62.31	61.83	61.44	62.02	61.60	57.59	59.9
Al ₂ O ₃	24.36	23.24	24.11	23.04	22.85	22.81	22.71	22.83	22.72	24.84	24.8
K ₂ O	0.11	3.94	0.18	0.09	0.06	0.09	0.07	0.07	0.05	0.29	0.08
CaO	5.86	4.94	5.72	4.36	4.19	4.15	4.20	4.36	4.30	6.17	6.55
Na ₂ O	7.87	6.35	8.31	9.19	9.37	9.57	9.21	9.14	9.19	7.56	7.9
FeO	0.24	0.41	0.50	0.18	0.14	0.20	0.00	0.02	0.03	0.44	0.19
SrO	0.10	0.09	0.08	0.06	0.07	0.08	0.06	0.12	0.08	0.11	0.18
BaO	0.19	0.00	0.02	0.04	0.15	0.00	0.09	0.07	0.25	0.00	0.18
Total	97.47	99.16	97.92	99.09	99.14	98.72	97.78	98.65	98.21	97.01	99.78

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.69	2.74	2.69	2.78	2.79	2.78	2.78	2.79	2.79	2.65	2.68
Al	1.31	1.25	1.30	1.22	1.21	1.21	1.21	1.21	1.21	1.35	1.31
K	0.01	0.23	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.02	0.00
Ca	0.29	0.24	0.28	0.21	0.20	0.20	0.20	0.21	0.21	0.30	0.31
Na	0.70	0.56	0.74	0.80	0.81	0.83	0.81	0.80	0.81	0.68	0.69
Fe	0.01	0.02	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.02	0.01
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Ab	70.4	54.4	71.7	78.8	79.9	80.3	79.6	78.8	79.2	67.7	68.3
% An	29.0	23.4	27.3	20.7	19.7	19.2	20.0	20.8	20.5	30.6	31.3
% Or	0.6	22.2	1.0	0.5	0.3	0.5	0.4	0.4	0.3	1.7	0.5

BLB97-101 Plagioclase (Continued)

Sample	P115	P116	P121	P122	P129	P130	P133	P134	P137	P138	P150
SiO ₂	56.71	55.30	55.69	60.34	59.59	60.23	64.00	64.18	62.27	64.52	59.65
Al ₂ O ₃	24.84	24.35	23.12	25.19	24.73	24.67	22.00	21.38	22.75	21.76	24.38
K ₂ O	0.07	0.32	0.10	0.08	0.09	0.10	0.08	0.06	0.21	0.07	0.06
CaO	6.83	5.65	5.35	6.62	6.20	6.42	3.01	2.71	3.95	2.79	5.99
Na ₂ O	6.91	6.40	7.38	7.63	8.19	8.08	10.11	10.13	9.23	10.07	8.24
FeO	2.69	1.78	5.28	0.70	0.48	0.18	0.09	0.08	0.11	0.14	0.17
SrO	0.14	0.14	0.07	0.12	0.10	0.05	0.09	0.05	0.05	0.09	0.06
BaO	0.15	0.00	0.05	0.13	0.00	0.04	0.05	0.11	0.08	0.00	0.00
Total	98.34	93.96	97.05	100.81	99.37	99.78	99.44	98.69	98.65	99.44	98.57
Number of cations in formula based on n oxygens											
n	8	8	8	8	8	8	8	8	8	8	8
Si	2.61	2.64	2.63	2.68	2.68	2.69	2.84	2.87	2.80	2.86	2.70
Al	1.35	1.37	1.29	1.32	1.31	1.30	1.15	1.13	1.20	1.14	1.30
K	0.00	0.02	0.01	0.00	0.01	0.01	0.00	0.00	0.01	0.00	0.00
Ca	0.34	0.29	0.27	0.31	0.30	0.31	0.14	0.13	0.19	0.13	0.29
Na	0.62	0.59	0.67	0.66	0.71	0.70	0.87	0.88	0.80	0.87	0.72
Fe	0.10	0.07	0.21	0.03	0.02	0.01	0.00	0.00	0.00	0.01	0.01
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
%Ab	64.4	65.8	70.9	67.3	70.1	69.1	85.5	86.8	79.9	86.4	71.1
%An	35.2	32.1	28.4	32.3	29.3	30.3	14.1	12.8	18.9	13.2	28.6
%Or	0.4	2.2	0.6	0.5	0.5	0.6	0.4	0.3	1.2	0.4	0.3

BLB97-101 Plagioclase (Continued)

Sample	P151	P152	P153	P154	P155	P156	P157	P158	P159	P160	P161
SiO ₂	59.52	58.87	58.39	60.00	58.61	59.87	60.00	60.08	59.96	60.09	60.00
Al ₂ O ₃	24.59	23.86	25.42	24.84	25.72	24.96	24.55	24.79	24.54	24.45	24.66
K ₂ O	0.08	4.80	0.07	0.28	2.16	0.14	0.15	0.09	0.06	0.23	0.44
CaO	6.02	4.67	7.28	6.24	5.09	6.89	6.20	6.26	6.38	6.13	6.36
Na ₂ O	8.31	5.52	7.56	7.46	6.29	7.34	7.64	7.64	7.54	7.58	7.33
FeO	0.29	0.33	0.50	0.11	0.32	0.13	0.07	0.11	0.18	0.15	0.14
SrO	0.12	0.06	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BaO	0.00	0.12	0.00	0.18	0.00	0.00	0.03	0.00	0.00	0.00	0.00
Total	98.92	98.23	99.33	99.11	98.19	99.33	98.64	98.96	98.67	98.64	98.93

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.69	2.71	2.63	2.70	2.67	2.68	2.70	2.70	2.70	2.71	2.70
Al	1.31	1.30	1.35	1.32	1.38	1.32	1.30	1.31	1.30	1.30	1.31
K	0.00	0.28	0.00	0.02	0.13	0.01	0.01	0.00	0.00	0.01	0.03
Ca	0.29	0.23	0.35	0.30	0.25	0.33	0.30	0.30	0.31	0.30	0.31
Na	0.73	0.49	0.66	0.65	0.55	0.64	0.67	0.66	0.66	0.66	0.64
Fe	0.01	0.01	0.02	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.01
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Ab	71.1	49.0	65.0	67.3	59.8	65.3	68.4	68.5	67.9	68.1	65.8
% An	28.5	22.9	34.6	31.1	26.7	33.9	30.7	31.0	31.8	30.5	31.6
% Or	0.5	28.1	0.4	1.7	13.5	0.8	0.9	0.5	0.4	1.4	2.6

BLB97-101 Plagioclase (Continued)

Sample	P162	P163	P164	P165	P166	P167	P168	P169	P170	P171	P172
SiO ₂	60.08	59.89	60.38	62.52	64.43	63.54	63.28	62.73	62.38	64.13	63.70
Al ₂ O ₃	25.02	24.69	24.37	23.20	22.25	22.67	22.63	22.93	22.91	21.61	22.47
K ₂ O	0.05	0.05	0.04	0.07	0.10	0.10	0.05	0.08	0.05	0.06	0.08
CaO	6.62	6.47	6.18	4.97	3.54	4.02	4.10	4.27	4.40	3.14	3.74
Na ₂ O	7.38	7.65	7.59	8.40	9.15	8.83	8.76	8.73	8.54	9.25	8.96
FeO	0.13	0.15	0.07	0.14	0.11	0.25	0.11	0.15	0.18	0.05	0.07
SiO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BaO	0.03	0.00	0.00	0.05	0.11	0.11	0.02	0.00	0.01	0.02	0.18
Total	99.31	98.91	98.63	99.35	99.68	99.53	98.96	98.88	98.47	98.27	99.20

Number of cations in formula based on n oxygens

	8	8	8	8	8	8	8	8	8	8	8
Si	2.69	2.69	2.72	2.78	2.85	2.82	2.82	2.80	2.80	2.87	2.83
Al	1.32	1.31	1.29	1.22	1.16	1.19	1.19	1.21	1.21	1.14	1.18
K	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
Ca	0.32	0.31	0.30	0.24	0.17	0.19	0.20	0.20	0.21	0.15	0.18
Na	0.64	0.67	0.66	0.72	0.78	0.76	0.76	0.76	0.74	0.80	0.77
Fe	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.01	0.00	0.00
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Ab	66.7	67.9	68.8	75.0	81.9	79.4	79.2	78.4	77.6	83.9	80.9
% An	33.0	31.8	30.9	24.5	17.5	20.0	20.5	21.2	22.1	15.7	18.6
% Or	0.3	0.3	0.3	0.4	0.6	0.6	0.3	0.5	0.3	0.4	0.5

BLB97-101 Plagioclase (Continued)

Sample	P173	P174	P175	P176	P177	P178	P179	P180	P181	P182	P183
SiO ₂	65.13	65.24	60.14	60.38	60.99	60.91	60.59	63.42	63.31	61.18	62.69
Al ₂ O ₃	21.46	21.40	24.43	24.56	24.18	24.27	24.71	22.71	22.78	24.16	22.95
K ₂ O	0.07	0.06	0.21	0.15	0.07	0.32	0.06	0.04	0.07	0.09	0.10
CaO	2.72	2.61	6.13	6.02	5.70	5.95	6.33	4.00	4.20	5.53	4.39
Na ₂ O	9.51	9.59	7.60	7.71	7.88	7.43	7.69	8.96	8.83	8.13	8.70
FeO	0.04	0.13	0.11	0.02	0.05	0.27	0.25	0.20	0.17	0.19	0.23
SrO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BaO	0.00	0.00	0.14	0.03	0.00	0.00	0.00	0.04	0.00	0.00	0.10
Total	98.93	99.02	98.74	98.87	98.87	99.15	99.63	99.37	99.36	99.28	99.16

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.89	2.89	2.71	2.71	2.73	2.73	2.70	2.82	2.81	2.73	2.80
Al	1.12	1.12	1.30	1.30	1.28	1.28	1.30	1.19	1.19	1.27	1.21
K	0.00	0.00	0.01	0.01	0.00	0.02	0.00	0.00	0.00	0.00	0.01
Ca	0.13	0.12	0.30	0.29	0.27	0.29	0.30	0.19	0.20	0.26	0.21
Na	0.82	0.82	0.66	0.67	0.68	0.64	0.67	0.77	0.76	0.70	0.75
Fe	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
%Ab	86.0	86.6	68.3	69.2	71.1	68.0	68.5	80.0	78.8	72.3	77.7
%An	13.6	13.0	30.4	29.9	28.4	30.1	31.1	19.7	20.7	27.2	21.7
%Or	0.4	0.3	1.2	0.9	0.4	2.0	0.4	0.2	0.4	0.5	0.6

BLB97-101 Plagioclase (Continued)

Sample	P184	P185	P186	P187	P188	P189	P190	P191	P192	P193	P194
SiO ₂	61.99	61.18	60.27	61.98	58.62	59.93	60.46	60.81	59.09	58.25	60.63
Al ₂ O ₃	22.64	22.94	23.75	22.82	24.91	24.14	24.72	24.70	25.52	25.23	24.36
K ₂ O	0.06	0.06	0.03	0.06	0.03	0.07	0.06	0.09	0.06	0.11	0.09
CaO	3.99	4.33	5.38	4.06	6.66	5.87	6.28	6.43	7.32	7.08	5.93
Na ₂ O	8.93	8.71	8.10	8.78	7.37	7.96	7.68	7.55	7.00	7.11	7.73
FeO	0.10	0.08	0.16	0.11	0.00	0.02	0.23	0.11	0.16	0.11	0.15
SrO	0.07	0.11	0.08	0.09	0.20	0.02	0.00	0.00	0.00	0.00	0.00
BaO	0.00	0.02	0.00	0.00	0.28	0.04	0.00	0.00	0.00	0.04	0.00
Total	97.78	97.44	97.78	97.90	98.08	98.04	99.43	99.69	99.15	97.93	98.88

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.80	2.78	2.73	2.80	2.67	2.71	2.70	2.71	2.65	2.65	2.72
Al	1.21	1.23	1.27	1.21	1.34	1.29	1.30	1.30	1.35	1.35	1.29
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01
Ca	0.19	0.21	0.26	0.20	0.33	0.28	0.30	0.31	0.35	0.35	0.28
Na	0.78	0.77	0.71	0.77	0.65	0.70	0.67	0.65	0.61	0.63	0.67
Fe	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.01
Sr	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
%Ab	79.9	78.2	73.0	79.3	66.6	70.8	68.7	67.6	63.2	64.1	69.9
%An	19.7	21.5	26.8	20.3	33.3	28.8	31.0	31.9	36.5	35.3	29.6
%Or	0.4	0.4	0.2	0.4	0.2	0.4	0.3	0.5	0.3	0.6	0.5

BLB97-101 Plagioclase (Continued)

Sample	P195	P196	P197	P198	P199	P200	P201	P202	P203	P204	P205
SiO ₂	61.30	62.40	62.97	63.11	62.79	63.08	63.46	62.21	63.84	61.12	56.24
Al ₂ O ₃	23.71	23.31	22.76	22.69	22.71	22.81	22.71	23.65	21.94	20.45	23.57
K ₂ O	0.08	0.10	0.06	0.06	0.10	0.07	0.07	0.83	1.13	0.56	0.59
CaO	5.80	4.62	4.35	3.97	4.39	4.33	4.16	4.88	3.37	5.62	5.52
Na ₂ O	7.64	8.47	8.82	8.85	8.70	8.64	8.75	7.69	8.18	5.93	7.25
FeO	0.12	0.14	0.16	0.25	0.27	0.06	0.03	0.52	0.56	1.85	2.68
SiO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BaO	0.05	0.06	0.05	0.00	0.00	0.03	0.05	0.12	0.17	0.13	0.00
Total	98.70	99.10	99.17	98.93	98.97	99.03	99.24	99.90	99.19	95.66	95.85

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.75	2.78	2.81	2.81	2.80	2.81	2.82	2.77	2.85	2.84	2.65
Al	1.25	1.23	1.20	1.19	1.19	1.20	1.19	1.24	1.15	1.12	1.31
K	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.05	0.06	0.03	0.04
Ca	0.28	0.22	0.21	0.19	0.21	0.21	0.20	0.23	0.16	0.28	0.28
Na	0.66	0.73	0.76	0.77	0.75	0.75	0.75	0.66	0.71	0.53	0.66
Fe	0.00	0.01	0.01	0.01	0.01	0.00	0.00	0.02	0.02	0.07	0.11
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Ab	70.1	76.4	78.3	79.8	77.7	78.0	78.8	70.3	75.8	63.0	67.8
% An	29.4	23.0	21.3	19.8	21.7	21.6	20.7	24.7	17.3	33.0	28.5
% Or	0.5	0.6	0.4	0.4	0.6	0.4	0.4	5.0	6.9	3.9	3.6

BLB97-101 Plagioclase (Continued)

Sample	P206	P207	P208	P209
SiO ₂	60.43	56.72	61.40	60.96
Al ₂ O ₃	23.48	24.24	23.27	23.76
K ₂ O	1.36	0.62	0.10	0.07
CaO	5.18	4.92	5.90	6.06
Na ₂ O	6.99	6.67	7.18	7.33
FeO	1.09	5.17	0.56	0.53
SrO	0.00	0.00	0.00	0.00
BaO	0.00	0.09	0.00	0.00
Total	98.53	98.44	98.41	98.72

Number of cations in formula based on n oxygens

n	8	8	8	8
Si	2.74	2.63	2.76	2.74
Al	1.25	1.32	1.23	1.26
K	0.08	0.04	0.01	0.00
Ca	0.25	0.24	0.28	0.29
Na	0.61	0.60	0.63	0.64
Fe	0.04	0.20	0.02	0.02
Sr	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00
% Ab	67.8	67.8	67.8	67.8
% An	28.5	28.5	28.5	28.5
% Or	3.6	3.6	3.6	3.6

MT98-101 Biotite

Sample	B33	B34	B33	B34	B46	B49	B68	B69	B87	B90	B97	B98	B111	B112
SiO ₂	34.61	34.56	33.62	34.12	36.48	33.68	35.12	34.58	34.87	35.26	35.65	35.91	35.16	36.14
Al ₂ O ₃	18.27	18.91	18.80	18.43	19.97	18.72	19.75	18.85	18.70	18.66	18.73	19.05	19.03	19.71
TiO ₂	1.71	1.59	1.60	1.54	1.41	1.51	1.07	1.62	1.62	1.45	1.62	1.59	1.30	1.28
Cr ₂ O ₃	0.07	0.08	0.06	0.05	0.02	0.13	0.18	0.02	0.08	0.05	0.08	0.07	0.09	0.07
FeO	16.01	15.99	16.42	19.34	15.28	15.90	15.10	16.21	15.90	16.06	16.13	16.02	15.86	16.07
MnO	0.05	0.09	0.02	0.00	0.07	0.09	0.07	0.05	0.11	0.03	0.02	0.06	0.09	0.00
K ₂ O	7.44	8.38	7.51	7.21	7.95	9.11	9.15	9.13	8.82	8.88	9.06	8.98	9.21	8.90
MgO	12.58	12.29	12.68	12.85	11.25	11.86	12.04	11.89	11.88	11.83	12.39	12.30	11.82	11.39
CaO	0.04	0.00	0.01	0.08	0.31	0.06	0.03	0.03	0.04	0.00	0.00	0.02	0.09	0.26
Na ₂ O	0.08	0.04	0.05	0.00	0.26	0.12	0.08	0.07	0.13	0.08	0.12	0.13	0.20	0.27
Cl	0.08	0.03	0.04	0.02	0.05	0.01	0.06	0.03	0.03	0.02	0.00	0.06	0.08	0.03
BaO	0.17	0.00	0.00	0.17	0.04	0.04	0.13	0.11	0.30	0.25	0.00	0.42	0.00	0.00
Total	91.29	92.32	91.04	94.10	93.27	91.53	93.00	92.81	92.56	92.78	93.90	94.89	92.92	94.19

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Si	2.94	2.91	2.87	2.86	3.00	2.89	2.93	2.91	2.94	2.96	2.95	2.95	2.95	2.97
Al iv	1.06	1.09	1.13	1.14	1.00	1.11	1.07	1.09	1.06	1.04	1.05	1.05	1.05	1.03
Al vi	0.77	0.79	0.76	0.68	0.94	0.78	0.87	0.78	0.79	0.81	0.78	0.80	0.83	0.89
Ti	0.11	0.10	0.10	0.10	0.09	0.10	0.07	0.10	0.10	0.09	0.10	0.10	0.08	0.08
Cr	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00
Fe	1.14	1.13	1.17	1.35	1.05	1.14	1.05	1.14	1.12	1.13	1.12	1.10	1.11	1.11
Mn	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00
K	0.81	0.90	0.82	0.77	0.83	1.00	0.97	0.98	0.95	0.95	0.96	0.94	0.98	0.93
Mg	1.59	1.54	1.61	1.60	1.38	1.52	1.50	1.49	1.49	1.48	1.53	1.51	1.48	1.40
Ca	0.00	0.00	0.00	0.01	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02
Na	0.01	0.01	0.01	0.00	0.04	0.02	0.01	0.01	0.02	0.01	0.02	0.02	0.03	0.04
Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.00	0.00
Fe/(Fe+Mg)	0.42	0.42	0.42	0.46	0.43	0.43	0.41	0.43	0.43	0.43	0.42	0.42	0.43	0.44

MT98-101 Biotite (Continued)

Sample	B117	B118	B127	B128	B131	B132	B139	B140	B147	B148	B149	B152	B153	B154
SiO ₂	34.96	34.94	33.49	35.03	34.24	35.43	32.84	34.40	33.80	42.21	42.76	34.18	34.82	34.73
Al ₂ O ₃	19.34	19.25	18.89	18.89	18.60	18.61	18.16	18.97	18.83	22.63	23.15	18.63	18.83	19.35
TiO ₂	1.36	1.43	1.37	1.49	1.47	1.52	1.50	1.53	1.28	1.33	1.31	1.41	1.40	1.45
Cr ₂ O ₃	0.10	0.13	0.12	0.07	0.10	0.11	0.11	0.08	0.00	0.06	0.05	0.01	0.00	0.06
FeO	16.44	16.53	17.59	16.20	17.02	16.22	20.36	16.26	15.84	15.81	15.23	15.29	15.64	16.10
MnO	0.04	0.05	0.08	0.09	0.05	0.10	0.15	0.11	0.02	0.06	0.07	0.12	0.13	0.11
K ₂ O	9.03	9.05	8.20	8.66	8.18	9.16	7.62	8.71	9.06	8.23	8.09	8.79	8.86	8.91
MgO	11.99	11.80	11.88	12.39	12.01	12.26	12.17	12.34	11.70	13.59	13.62	11.28	11.57	11.79
CaO	0.03	0.06	0.04	0.02	0.05	0.02	0.02	0.01	0.01	0.16	0.38	0.32	0.03	0.00
Na ₂ O	0.17	0.16	0.11	0.07	0.12	0.05	0.10	0.15	0.10	0.12	0.17	0.20	0.15	0.24
Cl	0.03	0.03	0.00	0.07	0.02	0.05	0.07	0.03	0.07	0.05	0.04	0.05	0.04	0.01
BaO	0.15	0.17	0.21	0.19	0.00	0.45	0.36	0.30	0.32	0.00	0.17	0.31	0.41	0.39
Total	93.89	93.79	92.19	93.34	91.98	94.13	93.60	93.16	91.19	104.33	105.05	90.60	91.87	93.13

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Si	2.91	2.92	2.86	2.93	2.91	2.95	2.80	2.89	2.91	3.07	3.07	2.94	2.95	2.91
Al iv	1.09	1.08	1.14	1.07	1.09	1.05	1.20	1.11	1.09	0.93	0.93	1.06	1.05	1.09
Al vi	0.81	0.81	0.76	0.79	0.77	0.77	0.63	0.77	0.81	1.02	1.02	0.83	0.84	0.82
Ti	0.09	0.09	0.09	0.09	0.09	0.10	0.10	0.10	0.08	0.07	0.07	0.09	0.09	0.09
Cr	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Fe	1.15	1.15	1.26	1.13	1.21	1.13	1.45	1.14	1.14	0.91	0.91	1.10	1.11	1.13
Mn	0.00	0.00	0.01	0.01	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.01
K	0.96	0.96	0.89	0.92	0.89	0.97	0.83	0.93	0.99	0.74	0.74	0.97	0.96	0.95
Mg	1.49	1.47	1.51	1.54	1.52	1.52	1.55	1.55	1.50	1.46	1.46	1.45	1.46	1.47
Ca	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.03	0.00	0.00
Na	0.03	0.03	0.02	0.01	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.04
Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.01
Fe/(Fe+Mg)	0.43	0.44	0.45	0.42	0.44	0.43	0.48	0.42	0.43	0.39	0.39	0.43	0.43	0.43

MT98-101 Biotite (Continued)

Sample	B155	B156	B157	B161	B162	B163	B164	B165	B166	B167	B168	B169	B170	B171
SiO ₂	38.82	35.54	35.77	32.50	35.18	33.75	35.59	35.55	36.44	35.07	32.65	34.53	35.00	35.10
Al ₂ O ₃	24.05	19.32	19.21	18.38	19.45	18.21	19.08	18.77	19.28	18.75	19.67	19.53	19.12	19.36
TiO ₂	1.33	1.62	1.59	1.58	1.47	1.54	1.78	1.64	1.69	1.59	1.17	1.43	1.61	1.59
Cr ₂ O ₃	0.10	0.07	0.14	0.10	0.17	0.13	0.12	0.11	0.13	0.08	0.14	0.10	0.03	0.01
FeO	13.27	16.16	16.04	20.11	15.66	18.30	15.88	15.95	15.11	15.63	18.40	17.37	16.43	16.20
MnO	0.10	0.13	0.03	0.06	0.10	0.08	0.07	0.03	0.06	0.09	0.04	0.07	0.07	0.13
K ₂ O	8.29	8.60	8.86	7.39	8.82	8.06	8.46	8.67	8.82	8.67	5.22	8.00	8.70	8.83
MgO	10.02	12.01	11.99	11.25	12.03	11.23	12.08	12.51	12.62	11.71	12.90	11.25	11.63	11.45
CaO	0.07	0.08	0.06	0.03	0.06	0.05	0.03	0.04	0.05	0.00	0.44	0.08	0.05	0.00
Na ₂ O	0.34	0.12	0.17	0.15	0.11	0.08	0.10	0.11	0.17	0.13	0.11	0.15	0.05	0.07
Cl	0.07	0.00	0.04	0.09	0.04	0.06	0.04	0.04	0.08	0.03	0.05	0.04	0.03	0.06
BaO	0.39	0.27	0.00	0.08	0.23	0.41	0.20	0.23	0.39	0.12	0.24	0.10	0.25	0.23
Total	96.87	93.91	93.90	91.71	93.31	91.88	93.44	93.63	94.84	91.87	91.02	92.65	92.97	93.03

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Si	3.02	2.94	2.95	2.81	2.93	2.90	2.95	2.95	2.97	2.96	2.78	2.91	2.93	2.94
Al iv	0.98	1.06	1.05	1.19	1.07	1.10	1.05	1.05	1.03	1.04	1.22	1.09	1.07	1.06
Al vi	1.22	0.82	0.82	0.69	0.84	0.74	0.82	0.78	0.82	0.83	0.76	0.84	0.82	0.85
Ti	0.08	0.10	0.10	0.10	0.09	0.10	0.11	0.10	0.10	0.10	0.08	0.09	0.10	0.10
Cr	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00
Fe	0.86	1.12	1.11	1.46	1.09	1.31	1.10	1.11	1.03	1.10	1.31	1.22	1.15	1.13
Mn	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.01
K	0.82	0.91	0.93	0.82	0.94	0.88	0.90	0.92	0.92	0.93	0.57	0.86	0.93	0.94
Mg	1.16	1.48	1.48	1.45	1.49	1.44	1.49	1.55	1.53	1.47	1.64	1.41	1.45	1.43
Ca	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.04	0.01	0.00	0.00
Na	0.05	0.02	0.03	0.03	0.02	0.01	0.02	0.02	0.03	0.02	0.02	0.02	0.01	0.01
Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.01	0.01
Fe/(Fe+Mg)	0.43	0.43	0.43	0.50	0.42	0.48	0.42	0.42	0.40	0.43	0.44	0.46	0.44	0.44

MT98-101 Biotite (Continued)

Sample	B172	B173	B174	B175	B176	B177	B178	B179	B180	B181	B182	B183	B186	B187
SiO ₂	34.85	35.30	35.21	35.69	34.61	34.87	35.45	35.68	35.44	34.86	35.22	35.10	35.71	35.53
Al ₂ O ₃	19.34	19.50	18.79	19.33	18.00	18.10	18.84	18.91	19.13	19.27	19.71	19.73	19.03	19.07
TiO ₂	1.50	1.40	1.62	1.60	1.54	1.54	1.60	1.68	1.33	1.40	1.71	1.78	1.63	1.59
Cr ₂ O ₃	0.02	0.00	0.11	0.14	0.00	0.07	0.13	0.15	0.12	0.11	0.04	0.16	0.12	0.10
FeO	15.99	16.00	16.13	15.59	15.93	16.01	15.85	16.14	15.59	16.10	15.58	15.27	16.16	16.27
MnO	0.05	0.08	0.10	0.11	0.12	0.06	0.12	0.08	0.03	0.05	0.03	0.00	0.09	0.04
K ₂ O	8.58	8.76	8.92	8.76	8.02	7.98	8.68	8.75	8.71	9.04	9.49	9.05	8.70	8.59
MgO	12.05	12.04	11.83	12.06	11.76	11.53	12.09	12.02	11.56	11.88	12.08	11.83	12.43	11.99
CaO	0.02	0.00	0.02	0.01	0.16	0.16	0.00	0.01	0.12	0.01	0.03	0.03	0.03	0.07
Na ₂ O	0.11	0.10	0.11	0.15	0.07	0.11	0.08	0.09	0.09	0.02	0.10	0.11	0.08	0.12
Cl	0.04	0.06	0.06	0.03	0.04	0.05	0.03	0.04	0.07	0.04	0.04	0.07	0.03	0.06
BaO	0.14	0.27	0.02	0.18	0.49	0.06	0.59	0.14	0.00	0.23	0.12	0.45	0.18	0.29
Total	92.68	93.51	92.92	93.65	90.73	90.53	93.46	93.69	92.19	93.01	94.15	93.58	94.20	93.70

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Si	2.92	2.93	2.95	2.95	2.97	2.99	2.95	2.96	2.97	2.92	2.91	2.92	2.94	2.95
Al iv	1.08	1.07	1.05	1.05	1.03	1.01	1.05	1.04	1.03	1.08	1.09	1.08	1.06	1.05
Al vi	0.83	0.84	0.80	0.84	0.79	0.81	0.80	0.81	0.87	0.83	0.83	0.85	0.79	0.81
Ti	0.09	0.09	0.10	0.10	0.10	0.10	0.10	0.11	0.08	0.09	0.11	0.11	0.10	0.10
Cr	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01
Fe	1.12	1.11	1.13	1.08	1.14	1.15	1.10	1.12	1.09	1.13	1.08	1.06	1.11	1.13
Mn	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.00
K	0.92	0.93	0.95	0.92	0.88	0.87	0.92	0.93	0.93	0.97	1.00	0.96	0.91	0.91
Mg	1.50	1.49	1.48	1.49	1.50	1.47	1.50	1.49	1.45	1.49	1.49	1.46	1.53	1.48
Ca	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01
Na	0.02	0.02	0.02	0.02	0.01	0.02	0.01	0.01	0.01	0.00	0.02	0.02	0.01	0.02
Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.01	0.00	0.01	0.02	0.00	0.02	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Fe/(Fe+Mg)	0.43	0.43	0.43	0.42	0.43	0.44	0.42	0.43	0.43	0.43	0.42	0.42	0.42	0.43

MT98-101 Biotite (Continued)

Sample	B188
SiO ₂	34.69
Al ₂ O ₃	19.04
TiO ₂	1.43
Cr ₂ O ₃	0.10
FeO	17.59
MnO	0.10
K ₂ O	8.41
MgO	11.89
CaO	0.00
Na ₂ O	0.12
Cl	0.05
BaO	0.16
Total	93.58

Number of cations in formula based on n oxygens

n	12
Si	2.90
Al iv	1.10
Al vi	0.78
Ti	0.09
Cr	0.01
Fe	1.23
Mn	0.01
K	0.90
Mg	1.48
Ca	0.00
Na	0.02
Cl	0.00
Ba	0.01
Fe/(Fe+Mg)	0.45

SAMPLE	M27	M28	M29	M30	M71	M72	M73	M74
NA2O	1.09	0.85	0.63	0.62	0.98	1.01	0.94	0.73
K2O	9.2	8.88	9.49	9.15	8.63	8.36	9.08	9.08
FEO	1.49	1.56	1.8	1.52	1.2	1.13	1.13	1.64
MGO	0.87	1.67	1.79	1.6	0.54	0.5	0.46	0.63
AL2O3	35.15	32.65	31.64	32.43	36.37	36.9	35.93	35.95
SIO2	44.16	45.35	46.16	46.18	44.32	44.81	44.22	43.94
CAO	0.01	0.03	0	0.02	0	0	0.03	0.06
TIO2	0.47	0.77	0.61	0.68	0.25	0.32	0.4	0.31
CR2O3	0.11	0.09	0.14	0.05	0.08	0.06	0	0.09
MNO	0	0.03	0	0.06	0	0.02	0.01	0.01
NIO	0.06	0	0.02	0	0	0.03	0.01	0.01
F	0	0	0	0	0	0	0	0.07
CL	0	0.01	0.01	0	0	0.03	0	0
NIO	0	0	0	0	0	0	0	0
SRO	0.03	0.08	0.09	0.09	0.05	0	0.09	0.01
BAO	0.88	0.61	0.57	0.44	1.25	0.92	1.07	0.9
ZNO	0.04	0	0	0.01	0	0	0	0
V2O3	0.03	0.17	0.11	0.05	0	0.02	0.08	0
P2O5	0	0.02	0.05	0.05	0.08	0	0.09	0
TOTAL	93.59	92.78	93.1	92.95	93.72	94.1	93.55	93.42

Sheet4

M75	M76	M99	M100	M101	M102	M103	M104	M105
1.1	0.87	0.9	0.71	0.8	0.73	0.82	0.85	1.01
9.08	8.84	8.79	8.66	9	8.75	8.93	8.81	9.48
0.99	1.03	1.48	1.75	1.41	1.33	1.77	1.37	1.07
0.47	0.47	1.72	1.5	1.25	1.5	1.92	1.57	1.09
36.63	36.49	33.12	33.1	33.76	33.13	32.66	33.64	34.35
44.21	43.96	46.06	46.14	46.54	46.62	46.02	46.46	45.34
0.03	0.04	0.03	0.04	0.01	0.03	0	0.03	0.03
0.33	0.28	0.61	0.69	0.73	0.64	0.65	0.68	0.62
0	0.09	0.05	0.02	0.07	0.14	0.08	0.14	0.03
0.04	0.03	0	0.04	0.03	0.08	0	0.07	0
0.03	0	0.01	0	0.03	0	0.03	0	0
0	0	0	0	0	0	0	0	0
0	0	0.01	0.02	0.01	0.02	0.02	0.01	0
0	0	0	0	0	0	0	0	0
0.08	0.08	0.11	0.08	0.01	0	0.05	0.06	0.14
0.75	0.94	0.66	0.65	0.88	0.51	0.37	0.62	0.31
0.05	0.03	0	0	0.03	0.05	0	0	0
0.06	0.01	0.09	0.05	0.13	0.1	0.08	0.06	0.04
0	0	0	0.05	0	0.06	0	0.02	0.18
93.85	93.17	93.63	93.5	94.71	93.69	93.4	94.37	93.68

M123	M124	M125	M126	M137	M138	M141	M142
2.37	0.92	0.73	0.67	0.82	0.73	0.76	1.02
6.14	9.23	9.07	9	9.46	9.35	9.2	8.63
1.3	1.13	1.18	1.19	1.42	1.62	1.37	1.16
0.36	0.43	1.01	0.7	1.52	1.77	1.51	0.77
32.95	36.29	34.12	35.82	32.77	32.55	32.78	35.5
48.92	44.61	45.61	44.48	45.91	47.1	46.41	44.58
2.09	0.16	0	0	0.03	0.02	0.01	0.03
0.26	0.25	0.52	0.3	0.63	0.64	0.6	0.47
0	0.04	0.03	0.01	0.08	0.03	0.16	0.11
0.03	0.04	0	0.06	0.07	0.02	0.05	0
0	0.01	0	0	0	0	0.02	0
0	0	0	0	0	0	0	0
0.01	0	0	0	0	0	0	0.02
0	0	0	0	0	0	0	0
0.03	0.1	0.01	0.03	0.05	0	0.05	0.02
0.69	0.68	0.22	0.72	0.33	0.29	0.61	0.51
0	0.07	0	0.07	0.03	0	0	0.03
0	0.04	0	0.08	0	0.17	0.16	0.06
0	0.06	0	0.02	0.08	0	0	0.12
95.15	94.07	92.49	93.16	93.21	94.29	93.69	93.03

MT98-102 Garnet

Sample	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11
SiO ₂	37.92	38.28	37.47	37.95	37.61	37.91	37.78	37.77	37.75	37.57	37.85
Al ₂ O ₃	21.30	21.50	21.54	21.39	21.49	21.10	21.24	21.05	21.01	20.91	20.78
TiO ₂	0.03	0.07	0.04	0.06	0.08	0.06	0.15	0.06	0.06	0.07	0.07
Cr ₂ O ₃	0.01	0.00	0.03	0.00	0.00	0.01	0.00	0.05	0.03	0.01	0.01
FeO	28.03	28.00	27.90	27.91	27.36	27.23	27.20	27.21	27.66	27.24	27.62
MnO	0.77	0.81	0.93	1.35	2.49	3.14	3.72	4.25	4.10	3.96	3.54
MgO	3.92	4.05	3.80	3.33	2.85	2.77	2.78	2.58	2.65	2.68	2.84
CaO	8.22	8.23	8.38	8.86	8.74	8.24	7.76	7.57	7.32	7.49	7.78
Na ₂ O	-	-	-	-	-	-	-	-	-	-	-
K ₂ O	-	-	-	-	-	-	-	-	-	-	-
Total	100.20	100.94	100.09	100.85	100.62	100.46	100.63	100.54	100.58	99.93	100.49

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	2.99	2.99	2.96	2.98	2.97	3.00	2.99	3.00	3.00	3.00	3.00
Al iv	0.01	0.01	0.04	0.02	0.03	0.00	0.01	0.00	0.00	0.00	0.00
Al vi	1.97	1.97	1.97	1.96	1.97	1.97	1.97	1.97	1.96	1.96	1.95
Ti	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe	1.85	1.83	1.84	1.83	1.81	1.80	1.80	1.81	1.84	1.82	1.83
Mn	0.05	0.05	0.06	0.09	0.17	0.21	0.25	0.29	0.28	0.27	0.24
Mg	0.46	0.47	0.45	0.39	0.34	0.33	0.33	0.31	0.31	0.32	0.34
Ca	0.69	0.69	0.71	0.75	0.74	0.70	0.66	0.64	0.62	0.64	0.66
Na	-	-	-	-	-	-	-	-	-	-	-
K	-	-	-	-	-	-	-	-	-	-	-
% Alm	60.5	60.1	60.2	59.9	59.3	59.3	59.3	59.4	60.2	59.7	59.7
% Sp	1.7	1.8	2.1	3.0	5.8	7.4	8.9	10.4	9.9	9.6	8.4
% Py	17.8	18.3	17.1	14.6	12.4	12.1	12.1	11.2	11.5	11.7	12.3
% Gr	29.4	29.3	30.1	32.2	32.0	29.9	27.7	26.9	25.7	26.6	27.5

MT98-102 Garnet (continued)

Sample	G12	G13	G14	G15	G16	G17	G18	G19	G20	G21	G22
SiO ₂	38.33	38.14	38.68	38.84	38.61	38.92	39.07	38.68	38.35	38.77	38.25
Al ₂ O ₃	20.87	20.94	21.22	21.25	21.30	21.51	21.24	21.21	21.36	21.23	21.31
TiO ₂	0.05	0.07	0.00	0.01	0.03	0.05	0.03	0.04	0.07	0.08	0.10
Cr ₂ O ₃	0.01	0.04	0.00	0.00	0.00	0.03	0.02	0.01	0.00	0.02	0.01
FeO	27.26	27.29	27.58	27.23	27.54	27.33	27.60	27.71	27.78	27.34	28.05
MnO	2.68	1.69	1.21	1.11	1.02	0.93	1.00	1.02	0.94	1.16	1.04
MgO	2.91	3.16	3.69	3.82	3.92	3.88	3.89	3.73	3.90	3.80	3.68
CaO	8.46	9.08	8.52	8.37	8.25	8.40	8.50	8.53	8.46	8.71	8.63
Na ₂ O	-	-	-	-	-	-	-	-	-	-	-
K ₂ O	-	-	-	-	-	-	-	-	-	-	-
Total	100.57	100.41	100.90	100.63	100.67	101.05	101.35	100.93	100.86	101.11	101.07

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	3.02	3.01	3.02	3.03	3.02	3.02	3.03	3.02	3.00	3.02	2.99
Al iv	-0.02	-0.01	-0.02	-0.03	-0.02	-0.02	-0.03	-0.02	0.00	-0.02	0.01
Al vi	1.96	1.95	1.98	1.99	1.98	2.00	1.98	1.97	1.97	1.97	1.96
Ti	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe	1.80	1.80	1.80	1.78	1.80	1.78	1.79	1.81	1.82	1.78	1.83
Mn	0.18	0.11	0.08	0.07	0.07	0.06	0.07	0.07	0.06	0.08	0.07
Mg	0.34	0.37	0.43	0.44	0.46	0.45	0.45	0.43	0.45	0.44	0.43
Ca	0.72	0.77	0.71	0.70	0.69	0.70	0.71	0.71	0.71	0.73	0.72
Na	-	-	-	-	-	-	-	-	-	-	-
K	-	-	-	-	-	-	-	-	-	-	-
% Alm	59.3	59.0	59.6	59.3	59.7	59.5	59.4	59.8	59.7	58.9	60.0
% Sp	6.3	3.8	2.7	2.5	2.3	2.1	2.2	2.3	2.1	2.6	2.3
% Py	12.7	13.9	16.6	17.4	17.9	17.7	17.6	16.8	17.6	17.1	16.3
% Gr	30.8	33.6	30.8	30.5	29.7	30.6	30.6	30.9	30.4	31.6	31.0

MT98-102 Garnet (continued)

Sample	G69	G70	G71	G72	G73	G74	G75	G76	G77	G78	G79
SiO ₂	37.76	37.86	38.24	37.54	38.09	38.00	37.95	37.61	37.85	37.95	37.73
Al ₂ O ₃	20.70	20.79	20.57	20.80	20.66	20.74	20.83	20.74	20.58	20.70	20.64
TiO ₂	0.09	0.07	0.09	0.01	0.07	0.07	0.10	0.15	0.14	0.09	0.04
Cr ₂ O ₃	0.05	0.06	0.00	0.08	0.00	0.11	0.04	0.05	0.02	0.02	0.02
FeO	27.24	26.98	27.30	27.36	27.28	27.58	27.31	26.42	26.32	27.30	27.25
MnO	1.37	1.42	1.38	1.64	2.00	1.73	2.57	3.16	3.22	3.26	2.85
MgO	3.53	3.45	3.50	3.04	2.86	2.98	2.70	2.68	2.63	2.70	2.79
CaO	8.76	8.77	8.65	8.90	8.91	8.76	8.73	8.87	8.87	8.73	8.44
Na ₂ O	-	-	-	-	-	-	-	-	-	-	-
K ₂ O	-	-	-	-	-	-	-	-	-	-	-
Total	99.50	99.40	99.73	99.37	99.87	99.97	100.23	99.68	99.63	100.75	99.76

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	3.00	3.01	3.03	3.00	3.02	3.01	3.01	3.00	3.02	3.00	3.01
Al iv	0.00	-0.01	-0.03	0.00	-0.02	-0.01	-0.01	0.00	-0.02	0.00	-0.01
Al vi	1.94	1.96	1.95	1.95	1.96	1.95	1.96	1.95	1.95	1.93	1.95
Ti	0.01	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.00
Cr	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Fe	1.81	1.79	1.81	1.83	1.81	1.83	1.81	1.76	1.76	1.81	1.82
Mn	0.09	0.10	0.09	0.11	0.13	0.12	0.17	0.21	0.22	0.22	0.19
Mg	0.42	0.41	0.41	0.36	0.34	0.35	0.32	0.32	0.31	0.32	0.33
Ca	0.75	0.75	0.73	0.76	0.76	0.74	0.74	0.76	0.76	0.74	0.72
Na	-	-	-	-	-	-	-	-	-	-	-
K	-	-	-	-	-	-	-	-	-	-	-
% Alm	59.0	58.9	59.3	59.7	59.5	60.1	59.5	57.7	57.7	58.6	59.3
% Sp	3.1	3.2	3.1	3.8	4.6	4.0	6.0	7.5	7.7	7.6	6.7
% Py	15.8	15.5	15.7	13.4	12.5	13.1	11.7	11.7	11.5	11.5	12.1
% Gr	32.1	32.5	31.7	33.1	33.2	32.4	32.2	33.0	33.2	31.6	30.8

MT98-102 Garnet (continued)

Sample	G80	G81	G82	G83	G84	G85	G86	G87	G88	G89	G90
SiO ₂	38.27	37.73	37.86	37.86	38.07	38.24	37.89	38.00	37.94	37.42	37.92
Al ₂ O ₃	20.50	20.45	20.60	20.44	20.46	20.46	20.67	20.23	20.36	20.28	20.25
TiO ₂	0.09	0.15	0.09	0.09	0.04	0.04	0.05	0.08	0.07	0.05	0.07
Cr ₂ O ₃	0.07	0.06	0.03	0.05	0.03	0.05	0.04	0.06	0.07	0.07	0.02
FeO	27.04	27.12	27.71	27.45	27.46	27.22	27.63	27.89	27.68	27.51	26.71
MnO	2.51	2.04	1.48	1.35	1.10	1.26	1.07	1.25	1.32	1.14	0.98
MgO	2.81	2.89	3.14	3.36	3.72	3.78	3.82	3.65	3.72	3.86	3.89
CaO	9.05	9.05	8.95	8.79	8.61	8.67	8.49	8.26	8.08	8.16	8.46
Na ₂ O	-	-	-	-	-	-	-	-	-	-	-
K ₂ O	-	-	-	-	-	-	-	-	-	-	-
Total	100.34	99.49	99.86	99.39	99.49	99.72	99.66	99.42	99.24	98.49	98.30

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	3.03	3.01	3.01	3.02	3.02	3.03	3.01	3.03	3.02	3.01	3.04
Al iv	-0.03	-0.01	-0.01	-0.02	-0.02	-0.03	-0.01	-0.03	-0.02	-0.01	-0.04
Al vi	1.94	1.94	1.94	1.94	1.94	1.94	1.94	1.93	1.94	1.93	1.95
Ti	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe	1.79	1.81	1.84	1.83	1.82	1.80	1.83	1.86	1.85	1.85	1.79
Mn	0.17	0.14	0.10	0.09	0.07	0.08	0.07	0.08	0.09	0.08	0.07
Mg	0.33	0.34	0.37	0.40	0.44	0.45	0.45	0.43	0.44	0.46	0.46
Ca	0.77	0.77	0.76	0.75	0.73	0.74	0.72	0.70	0.69	0.70	0.73
Na	-	-	-	-	-	-	-	-	-	-	-
K	-	-	-	-	-	-	-	-	-	-	-
% Alm	58.5	59.0	59.9	59.6	59.4	58.7	59.5	60.3	60.2	59.8	58.7
% Sp	5.8	4.7	3.3	3.1	2.5	2.8	2.4	2.8	3.0	2.6	2.2
% Py	12.2	12.6	13.8	14.9	16.7	17.0	17.2	16.4	16.8	17.6	18.0
% Gr	33.5	33.8	32.9	32.4	31.3	31.5	30.6	29.7	29.0	29.4	31.3

MT98-102 Garnet (continued)

Sample	G91	G92	G93	G94	G95	G111	G112	G113	G114	G115	G116
SiO ₂	37.79	38.00	37.71	37.91	38.54	38.26	38.21	38.39	38.49	38.08	38.20
Al ₂ O ₃	20.44	20.42	19.53	20.95	20.90	21.05	20.94	21.40	21.13	20.77	20.77
TiO ₂	0.07	0.07	0.07	0.08	0.06	0.03	0.03	0.00	0.00	0.05	0.09
Cr ₂ O ₃	0.05	0.04	0.03	0.05	0.09	0.01	0.00	0.00	0.09	0.05	0.05
FeO	27.67	27.58	27.07	26.91	26.43	27.84	28.37	28.42	28.01	27.22	26.88
MnO	0.90	0.95	1.66	1.66	1.63	0.89	0.97	0.96	1.37	2.25	3.17
MgO	3.98	3.94	3.06	3.01	3.05	3.71	3.72	3.65	3.23	2.84	2.83
CaO	8.41	8.33	9.06	9.34	9.14	8.59	8.66	8.35	8.68	8.92	8.72
Na ₂ O	-	-	-	-	-	-	-	-	-	-	-
K ₂ O	-	-	-	-	-	-	-	-	-	-	-
Total	99.31	99.33	98.19	99.91	99.84	100.38	100.90	101.17	101.00	100.18	100.71

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	3.01	3.02	3.05	3.00	3.04	3.01	3.00	3.00	3.02	3.02	3.02
Al iv	-0.01	-0.02	-0.05	0.00	-0.04	-0.01	0.00	0.00	-0.02	-0.02	-0.02
Al vi	1.93	1.94	1.91	1.96	1.99	1.96	1.94	1.97	1.97	1.96	1.95
Ti	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Cr	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00
Fe	1.84	1.83	1.83	1.78	1.74	1.83	1.86	1.86	1.84	1.80	1.77
Mn	0.06	0.06	0.11	0.11	0.11	0.06	0.06	0.06	0.09	0.15	0.21
Mg	0.47	0.47	0.37	0.36	0.36	0.44	0.44	0.43	0.38	0.34	0.33
Ca	0.72	0.71	0.78	0.79	0.77	0.72	0.73	0.70	0.73	0.76	0.74
Na	-	-	-	-	-	-	-	-	-	-	-
K	-	-	-	-	-	-	-	-	-	-	-
% Alm	59.6	59.6	59.1	58.6	58.4	60.0	60.3	61.0	60.5	59.2	58.0
% Sp	2.0	2.1	3.8	3.8	3.8	2.0	2.1	2.1	3.1	5.2	7.4
% Py	18.0	17.9	13.5	13.2	13.7	16.6	16.4	16.2	14.2	12.4	12.2
% Gr	30.2	30.0	33.9	35.2	34.9	31.1	30.8	29.8	31.6	33.1	31.8

MT98-102 Garnet (continued)

Sample	G117	G118	G119	G120	G121	G122	G123	G124	G125	G126	G127
SiO ₂	38.61	38.09	37.56	37.91	38.09	38.27	38.10	38.12	37.78	38.02	37.99
Al ₂ O ₃	21.00	20.66	20.84	20.85	20.87	20.95	20.84	20.87	20.96	21.07	20.61
TiO ₂	0.00	0.01	0.05	0.09	0.10	0.32	0.10	0.09	0.07	0.10	0.07
Cr ₂ O ₃	0.02	0.11	0.10	0.01	0.02	0.01	0.02	0.00	0.03	0.00	0.02
FeO	27.14	27.65	26.94	27.80	26.88	27.30	27.11	27.70	27.37	27.07	27.25
MnO	3.30	3.59	3.64	3.88	3.74	3.30	3.13	2.94	2.64	2.55	1.94
MgO	2.80	3.01	2.69	2.71	2.83	2.97	2.88	2.70	2.82	2.83	2.88
CaO	7.87	7.28	7.72	7.24	8.01	7.90	8.15	8.46	8.81	9.08	9.37
Na ₂ O	-	-	-	-	-	-	-	-	-	-	-
K ₂ O	-	-	-	-	-	-	-	-	-	-	-
Total	100.74	100.40	99.54	100.49	100.54	101.02	100.33	100.88	100.48	100.72	100.13

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	3.04	3.02	3.00	3.01	3.01	3.01	3.02	3.01	2.99	3.00	3.01
Al iv	-0.04	-0.02	0.00	-0.01	-0.01	-0.01	-0.02	-0.01	0.01	0.00	-0.01
Al vi	1.99	1.95	1.97	1.96	1.96	1.95	1.96	1.95	1.95	1.96	1.94
Ti	0.00	0.00	0.00	0.01	0.01	0.02	0.01	0.01	0.00	0.01	0.00
Cr	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe	1.79	1.83	1.80	1.85	1.78	1.80	1.79	1.83	1.81	1.78	1.81
Mn	0.22	0.24	0.25	0.26	0.25	0.22	0.21	0.20	0.18	0.17	0.13
Mg	0.33	0.36	0.32	0.32	0.33	0.35	0.34	0.32	0.33	0.33	0.34
Ca	0.66	0.62	0.66	0.62	0.68	0.67	0.69	0.72	0.75	0.77	0.80
Na	-	-	-	-	-	-	-	-	-	-	-
K	-	-	-	-	-	-	-	-	-	-	-
% Alm	59.6	60.1	59.5	60.6	58.5	59.3	59.1	59.8	59.0	58.4	58.8
% Sp	7.9	8.6	8.9	9.4	9.0	7.8	7.4	6.9	6.1	5.9	4.4
% Py	12.3	13.2	11.8	11.8	12.3	13.0	12.6	11.6	12.2	12.2	12.5
% Gr	28.4	25.4	27.9	25.4	28.7	28.2	29.5	30.5	32.2	33.5	34.9

MT98-102 Garnet (continued)

Sample	G128	G129	G130	G131	G132	G133	G134	G135	G136	G137	G165
SiO ₂	38.47	38.47	38.19	38.53	38.02	38.37	38.10	35.89	40.95	40.67	37.66
Al ₂ O ₃	20.86	20.85	20.87	21.18	20.72	20.79	20.66	19.27	22.23	21.76	20.66
TiO ₂	0.05	0.06	0.06	0.03	0.10	0.05	0.07	0.01	0.03	0.05	0.19
Cr ₂ O ₃	0.04	0.07	0.05	0.01	0.02	0.03	0.04	0.04	0.08	0.00	0.04
FeO	27.31	27.26	28.05	28.39	25.77	27.72	26.17	25.56	25.43	25.66	25.35
MnO	1.66	1.54	1.67	1.48	3.16	2.60	2.55	3.49	3.53	2.22	3.21
MgO	2.89	2.85	2.99	3.13	3.00	3.07	3.07	2.53	3.06	3.24	2.97
CaO	9.31	9.26	9.02	8.93	9.16	8.56	8.76	8.54	8.90	8.93	9.03
Na ₂ O	-	-	-	-	-	-	-	-	-	-	-
K ₂ O	-	-	-	-	-	-	-	-	-	-	-
Total	100.59	100.36	100.90	101.68	99.95	101.19	99.42	95.33	104.21	102.53	99.11

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	3.03	3.03	3.01	3.01	3.01	3.01	3.03	3.01	3.08	3.10	3.01
Al iv	-0.03	-0.03	-0.01	-0.01	-0.01	-0.01	-0.03	-0.01	-0.08	-0.10	-0.01
Al vi	1.96	1.97	1.94	1.95	1.95	1.94	1.97	1.91	2.05	2.05	1.95
Ti	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe	1.80	1.80	1.85	1.85	1.71	1.82	1.74	1.79	1.60	1.63	1.69
Mn	0.11	0.10	0.11	0.10	0.21	0.17	0.17	0.25	0.22	0.14	0.22
Mg	0.34	0.33	0.35	0.36	0.35	0.36	0.36	0.32	0.34	0.37	0.35
Ca	0.79	0.78	0.76	0.75	0.78	0.72	0.75	0.77	0.72	0.73	0.77
Na	-	-	-	-	-	-	-	-	-	-	-
K	-	-	-	-	-	-	-	-	-	-	-
% Alm	59.3	59.6	60.2	60.5	56.0	59.2	57.6	57.4	55.4	56.9	55.8
% Sp	3.8	3.5	3.8	3.3	7.5	6.0	6.0	8.6	8.5	5.2	7.7
% Py	12.6	12.5	12.9	13.5	13.1	13.2	13.7	11.3	13.5	14.7	13.2
% Gr	34.9	35.0	33.0	32.3	34.2	30.6	32.8	32.6	33.1	34.0	34.1

MT98-102 Garnet (continued)

Sample	G166	G167	G168	G169	G170	G171	G172	G173	G174	G175	G176
SiO ₂	37.94	38.70	40.81	40.30	38.22	38.36	38.19	38.32	38.55	38.39	38.41
Al ₂ O ₃	20.61	21.34	22.43	22.35	21.33	21.34	21.45	21.02	21.16	21.26	21.09
TiO ₂	0.17	0.12	0.11	0.14	0.13	0.11	0.15	0.01	0.09	0.04	0.06
Cr ₂ O ₃	0.08	0.07	0.00	0.09	0.07	0.12	0.00	0.00	0.04	0.07	0.10
FeO	26.33	26.18	25.22	25.28	27.02	26.97	27.23	27.33	27.66	27.77	27.46
MnO	2.88	2.80	4.56	4.22	2.98	2.80	2.67	1.18	1.07	1.02	1.46
MgO	2.86	2.75	2.94	2.56	2.76	2.81	2.81	3.39	3.38	3.37	3.10
CaO	9.18	9.09	8.29	8.40	8.73	8.73	8.83	8.32	8.65	8.41	8.78
Na ₂ O	-	-	-	-	-	-	-	-	-	-	-
K ₂ O	-	-	-	-	-	-	-	-	-	-	-
Total	100.05	101.05	104.36	103.34	101.24	101.24	101.33	99.57	100.60	100.33	100.46

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	3.01	3.03	3.07	3.06	3.00	3.00	2.99	3.03	3.02	3.02	3.02
Al iv	-0.01	-0.03	-0.07	-0.06	0.00	0.00	0.01	-0.03	-0.02	-0.02	-0.02
Al vi	1.94	1.99	2.05	2.06	1.97	1.97	1.97	1.99	1.98	1.99	1.98
Ti	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.00
Cr	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.01
Fe	1.75	1.71	1.59	1.61	1.77	1.77	1.78	1.81	1.81	1.83	1.81
Mn	0.19	0.19	0.29	0.27	0.20	0.19	0.18	0.08	0.07	0.07	0.10
Mg	0.34	0.32	0.33	0.29	0.32	0.33	0.33	0.40	0.40	0.40	0.36
Ca	0.78	0.76	0.67	0.68	0.73	0.73	0.74	0.71	0.73	0.71	0.74
Na	-	-	-	-	-	-	-	-	-	-	-
K	-	-	-	-	-	-	-	-	-	-	-
% Alm	57.1	57.5	55.2	56.3	58.6	58.6	58.9	60.4	60.3	60.9	60.1
% Sp	6.8	6.6	11.2	10.5	7.0	6.6	6.2	2.7	2.4	2.3	3.3
% Py	12.4	12.1	13.0	11.3	11.9	12.2	12.1	15.4	15.1	15.2	13.8
% Gr	34.2	34.3	30.3	31.5	32.0	32.1	32.4	30.8	31.9	31.0	32.6

MT98-102 Garnet (continued)

Sample	G177	G178	G179	G180	G181	G182	G183	G184	G185	G186	G187
SiO ₂	38.17	38.08	38.88	38.37	37.84	38.29	38.17	37.50	37.63	37.56	37.46
Al ₂ O ₃	21.14	21.09	21.08	21.14	21.13	21.15	20.62	21.32	21.23	21.27	21.35
TiO ₂	0.17	0.14	0.08	0.13	0.06	0.01	0.07	0.12	0.15	0.13	0.05
Cr ₂ O ₃	0.07	0.12	0.02	0.00	0.03	0.00	0.00	0.00	0.04	0.05	0.00
FeO	27.12	27.75	27.35	26.94	27.18	27.60	27.68	27.29	27.26	26.89	27.36
MnO	1.85	1.78	1.69	2.24	2.17	2.54	2.55	1.20	1.14	1.23	1.02
MgO	3.09	2.98	2.96	2.78	2.77	2.87	2.58	3.45	3.48	3.34	3.78
CaO	8.94	9.18	8.91	9.02	8.86	8.51	8.59	8.91	8.91	8.88	8.25
Na ₂ O	-	-	-	-	-	-	-	0.00	0.02	0.00	0.00
K ₂ O	-	-	-	-	-	-	-	0.00	0.00	0.00	0.01
Total	100.55	101.12	100.97	100.62	100.04	100.97	100.26	99.81	99.86	99.36	99.28

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	3.00	2.99	3.04	3.02	3.00	3.01	3.03	2.97	2.98	2.98	2.98
Al iv	0.00	0.01	-0.04	-0.02	0.00	-0.01	-0.03	0.03	0.02	0.02	0.02
Al vi	1.96	1.94	1.98	1.98	1.97	1.97	1.96	1.96	1.96	1.98	1.98
Ti	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.01	0.00
Cr	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe	1.78	1.82	1.79	1.77	1.80	1.81	1.84	1.81	1.80	1.79	1.82
Mn	0.12	0.12	0.11	0.15	0.15	0.17	0.17	0.08	0.08	0.08	0.07
Mg	0.36	0.35	0.35	0.33	0.33	0.34	0.31	0.41	0.41	0.40	0.45
Ca	0.75	0.77	0.75	0.76	0.75	0.72	0.73	0.76	0.76	0.76	0.70
Na	-	-	-	-	-	-	-	0.00	0.00	0.00	0.00
K	-	-	-	-	-	-	-	0.00	0.00	0.00	0.00
% Alm	59.0	59.5	59.8	58.9	59.5	59.7	60.3	59.2	59.2	59.1	59.9
% Sp	4.3	4.0	3.9	5.2	5.1	5.9	6.0	2.7	2.6	2.8	2.3
% Py	13.6	12.9	13.0	12.2	12.1	12.5	11.1	15.4	15.6	15.1	17.3
% Gr	33.2	33.7	33.2	33.8	33.1	30.9	31.6	32.9	33.0	33.4	30.1

MT98-102 Garnet (continued)

Sample	G188	G189	G190	G191	G192	G193	G194	G195	G196	G197	G198
SiO ₂	37.29	37.34	37.04	37.21	37.29	37.48	36.68	36.97	37.28	37.02	37.20
Al ₂ O ₃	21.38	21.29	21.42	21.37	21.26	21.38	21.30	21.15	21.17	21.31	21.39
TiO ₂	0.03	0.06	0.06	0.09	0.04	0.07	0.09	0.08	0.09	0.11	0.06
Cr ₂ O ₃	0.00	0.00	0.04	0.00	0.00	0.01	0.10	0.03	0.03	0.03	0.04
FeO	27.47	27.41	27.17	27.64	27.29	27.26	26.95	27.32	27.17	27.55	27.68
MnO	0.88	0.93	0.83	0.71	0.77	0.77	0.84	0.93	1.00	1.16	1.17
MgO	3.91	3.87	3.94	3.97	4.08	4.15	3.86	3.86	3.86	3.71	3.65
CaO	8.18	8.38	8.55	8.37	8.43	8.07	8.19	8.69	8.54	8.62	8.40
Na ₂ O	0.00	0.00	0.02	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00
K ₂ O	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.00	0.00	0.00	0.01
Total	99.14	99.29	99.07	99.36	99.17	99.21	98.04	99.05	99.13	99.52	99.61

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	2.97	2.97	2.95	2.96	2.97	2.98	2.95	2.95	2.97	2.95	2.96
Al iv	0.03	0.03	0.05	0.04	0.03	0.02	0.05	0.05	0.03	0.05	0.04
Al vi	1.97	1.97	1.96	1.96	1.96	1.98	1.97	1.95	1.96	1.95	1.96
Ti	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.00
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Fe	1.83	1.82	1.81	1.84	1.82	1.81	1.81	1.83	1.81	1.83	1.84
Mn	0.06	0.06	0.06	0.05	0.05	0.05	0.06	0.06	0.07	0.08	0.08
Mg	0.46	0.46	0.47	0.47	0.48	0.49	0.46	0.46	0.46	0.44	0.43
Ca	0.70	0.71	0.73	0.71	0.72	0.69	0.71	0.74	0.73	0.74	0.72
Na	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Alm	59.9	59.6	59.1	59.9	59.2	59.5	59.7	59.0	59.1	59.4	60.0
% Sp	2.0	2.1	1.9	1.6	1.7	1.7	1.9	2.1	2.2	2.6	2.6
% Py	18.0	17.7	18.0	18.1	18.7	19.3	18.0	17.5	17.6	16.6	16.4
% Gr	29.7	30.5	31.3	30.3	30.5	29.2	30.2	31.7	31.2	31.2	30.4

MT98-102 Garnet (continued)

Sample	G199	G200	G201	G202	G203	G204	G205	G206	G207	G208	G209
SiO ₂	37.37	36.98	37.16	37.01	37.07	37.38	37.20	36.25	37.30	37.09	37.11
Al ₂ O ₃	21.41	21.54	21.31	21.25	21.28	21.24	21.32	21.40	21.44	21.33	21.41
TiO ₂	0.08	0.06	0.09	0.07	0.09	0.08	0.07	0.08	0.05	0.11	0.06
Cr ₂ O ₃	0.01	0.00	0.02	0.06	0.00	0.00	0.02	0.05	0.02	0.02	0.06
FeO	27.87	27.77	28.17	27.82	27.65	27.46	27.50	27.47	27.84	27.68	27.60
MnO	1.23	0.95	0.75	0.77	0.65	0.69	0.63	0.83	0.97	0.78	1.18
MgO	3.68	3.72	3.88	4.03	3.99	3.90	3.96	3.60	3.65	3.85	3.65
CaO	8.38	8.61	8.25	8.26	8.37	8.54	8.19	8.29	8.44	8.46	8.54
Na ₂ O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00
K ₂ O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00
Total	100.03	99.64	99.64	99.28	99.10	99.29	98.89	98.00	99.71	99.36	99.59

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	2.96	2.94	2.95	2.95	2.96	2.97	2.97	2.93	2.96	2.95	2.95
Al iv	0.04	0.06	0.05	0.05	0.04	0.03	0.03	0.07	0.04	0.05	0.05
Al vi	1.96	1.96	1.95	1.95	1.96	1.96	1.97	1.97	1.97	1.95	1.96
Ti	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.01	0.00	0.01	0.00
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe	1.85	1.85	1.87	1.85	1.84	1.83	1.83	1.86	1.85	1.84	1.84
Mn	0.08	0.06	0.05	0.05	0.04	0.05	0.04	0.06	0.07	0.05	0.08
Mg	0.43	0.44	0.46	0.48	0.47	0.46	0.47	0.43	0.43	0.46	0.43
Ca	0.71	0.73	0.70	0.71	0.72	0.73	0.70	0.72	0.72	0.72	0.73
Na	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Alm	60.1	59.9	60.7	60.0	59.9	59.6	60.2	60.6	60.3	59.9	59.7
% Sp	2.8	2.1	1.7	1.7	1.4	1.5	1.4	1.9	2.2	1.7	2.6
% Py	16.5	16.7	17.5	18.3	18.2	17.8	18.3	16.5	16.4	17.5	16.4
% Gr	30.1	31.2	29.5	29.6	30.3	31.1	29.8	30.6	30.6	30.7	31.0

MT98-102 Garnet (continued)

Sample	G210	G211	G212	G213	G215	G216	G217	G218	G219	G220
SiO ₂	37.54	37.47	37.14	37.03	37.04	36.71	36.77	36.73	38.00	38.04
Al ₂ O ₃	21.60	21.41	21.30	21.23	21.32	21.09	21.25	21.51	21.57	21.82
TiO ₂	0.04	0.10	0.05	0.08	0.08	0.09	0.09	0.01	0.11	0.12
Cr ₂ O ₃	0.06	0.06	0.04	0.02	0.05	0.05	0.00	0.09	0.02	0.04
FeO	27.47	27.57	27.29	27.31	27.30	27.62	27.77	27.39	27.21	27.09
MnO	1.26	1.09	1.03	0.99	1.43	1.27	1.41	1.60	1.54	1.58
MgO	3.82	3.75	3.86	3.84	3.54	3.46	3.47	2.98	2.93	2.98
CaO	8.33	8.45	8.52	8.36	8.45	8.38	8.30	8.62	9.10	9.33
Na ₂ O	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K ₂ O	0.00	0.00	0.02	0.04	0.01	0.01	0.00	0.01	0.02	0.00
Total	100.13	99.93	99.24	98.90	99.22	98.68	99.06	98.93	100.49	100.99

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12
Si	2.96	2.96	2.96	2.96	2.96	2.95	2.95	2.95	2.99	2.98
Al iv	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.01	0.02
Al vi	1.97	1.96	1.96	1.96	1.96	1.95	1.95	1.98	1.99	1.99
Ti	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.01
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Fe	1.81	1.82	1.82	1.83	1.82	1.86	1.86	1.84	1.79	1.77
Mn	0.08	0.07	0.07	0.07	0.10	0.09	0.10	0.11	0.10	0.10
Mg	0.45	0.44	0.46	0.46	0.42	0.42	0.41	0.36	0.34	0.35
Ca	0.70	0.72	0.73	0.72	0.72	0.72	0.71	0.74	0.77	0.78
Na	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Alm	59.4	59.7	59.2	59.5	59.5	60.3	60.3	60.4	59.6	58.9
% Sp	2.8	2.5	2.3	2.2	3.2	2.9	3.2	3.7	3.5	3.6
% Py	17.3	16.9	17.5	17.5	15.9	15.6	15.5	13.3	12.9	13.1
% Gr	30.0	30.6	31.0	30.5	30.9	30.6	30.1	32.2	34.3	35.2

MT98-102 Hornblende

Sample	H23	H24	H25	H26	H27	H45	H46	H47	H48	H49	H50
SiO ₂	39.14	43.25	43.67	42.52	41.96	40.49	40.38	40.80	43.62	40.64	41.11
Al ₂ O ₃	28.18	12.12	11.90	14.43	14.46	14.46	14.46	13.88	11.66	14.78	14.80
TiO ₂	0.15	0.13	0.10	0.65	0.58	0.65	0.58	0.08	0.06	0.16	0.10
Cr ₂ O ₃	0.03	0.01	0.03	0.05	0.10	0.03	0.06	0.02	0.03	0.02	0.00
FeO	6.02	19.62	19.92	18.35	17.58	20.98	21.68	21.91	21.17	21.91	21.85
MnO	0.16	0.34	0.28	0.23	0.25	0.26	0.18	0.25	0.25	0.23	0.25
K ₂ O	0.00	0.40	0.38	0.43	0.43	0.59	0.61	0.49	0.38	0.56	0.55
MgO	0.00	8.00	8.16	8.33	8.48	6.39	6.53	6.59	7.97	6.13	6.20
CaO	23.77	11.79	11.75	11.05	11.76	11.72	11.94	11.67	11.84	11.85	11.74
Na ₂ O	0.01	0.92	0.95	1.34	1.05	1.15	1.17	1.05	0.81	1.04	1.02
CL	0.03	0.04	0.02	0.03	0.02	0.10	0.08	0.06	0.03	0.04	0.05
F	0.00	0.03	0.00	0.00	0.00	0.04	0.07	0.04	0.05	0.01	0.05
Total	97.49	96.65	97.16	97.41	96.67	96.86	97.74	96.84	97.87	97.37	97.72

Number of cations in formula based on n oxygens

n	23	23	23	23	23	23	23	23	23	23	23
Si	5.66	6.61	6.63	6.39	6.35	6.25	6.21	6.32	6.62	6.26	6.29
Al iv	2.34	1.39	1.37	1.61	1.65	1.75	1.79	1.68	1.38	1.74	1.71
Al vi	2.46	0.79	0.77	0.95	0.93	0.88	0.83	0.85	0.71	0.94	0.97
Ti	0.02	0.01	0.01	0.07	0.07	0.08	0.07	0.01	0.01	0.02	0.01
Cr	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00
Fe	0.73	2.51	2.53	2.31	2.23	2.71	2.79	2.84	2.69	2.82	2.80
Mn	0.02	0.04	0.04	0.03	0.03	0.03	0.02	0.03	0.03	0.03	0.03
K	0.00	0.08	0.07	0.08	0.08	0.12	0.12	0.10	0.07	0.11	0.11
Mg	0.00	1.82	1.85	1.87	1.91	1.47	1.50	1.52	1.80	1.41	1.42
Ca	3.68	1.93	1.91	1.78	1.91	1.94	1.97	1.94	1.93	1.95	1.93
Na	0.00	0.27	0.28	0.39	0.31	0.34	0.35	0.32	0.24	0.31	0.30
Cl	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00
F	0.00	0.01	0.00	0.00	0.00	0.02	0.03	0.02	0.02	0.00	0.02
Fe/Fe+Mg	1.00	0.58	0.58	0.55	0.54	0.65	0.65	0.65	0.60	0.67	0.66

MT98-102 Hornblende (continued)

Sample	H51	H52	H53	H54	H55	H56	H107	H108	H109	H110	H157
SiO ₂	40.21	41.49	41.67	42.63	40.49	41.18	43.56	42.30	42.43	42.65	42.77
Al ₂ O ₃	14.62	14.32	13.26	12.96	14.38	13.26	12.04	13.51	13.41	13.78	14.23
TiO ₂	0.16	0.19	0.26	0.22	0.27	0.38	0.40	0.55	0.66	0.71	0.65
Cr ₂ O ₃	0.09	0.06	0.08	0.06	0.00	0.03	0.01	0.00	0.08	0.16	0.10
FeO	21.19	21.33	21.56	20.97	22.20	22.81	18.94	19.02	17.96	17.99	16.18
MnO	0.27	0.35	0.27	0.26	0.22	0.32	0.19	0.27	0.12	0.16	0.05
K ₂ O	0.55	0.38	0.35	0.33	0.52	0.48	0.26	0.35	0.37	0.34	0.44
MgO	5.96	6.35	6.53	7.18	5.80	6.37	8.75	8.22	8.81	8.77	9.42
CaO	11.65	11.48	11.47	11.61	11.60	11.70	11.93	11.98	12.16	12.19	11.19
Na ₂ O	1.05	1.16	1.12	1.12	1.08	1.04	0.98	1.03	0.98	0.95	1.46
CL	0.03	0.00	0.00	0.00	0.02	0.01	0.00	0.00	0.00	0.00	0.00
F	0.02	0.02	0.04	0.03	0.06	0.05	0.00	0.02	0.05	0.02	0.06
Total	95.80	97.13	96.61	97.37	96.64	97.63	97.06	97.25	97.03	97.72	96.55

Number of cations in formula based on n oxygens

n	23	23	23	23	23	23	23	23	23	23	23
Si	6.28	6.37	6.44	6.50	6.29	6.35	6.59	6.41	6.42	6.40	6.43
Al iv	1.72	1.63	1.56	1.50	1.71	1.65	1.41	1.59	1.58	1.60	1.57
Al vi	0.97	0.95	0.85	0.83	0.92	0.76	0.74	0.82	0.80	0.83	0.95
Ti	0.02	0.02	0.03	0.03	0.03	0.04	0.05	0.06	0.08	0.08	0.07
Cr	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.02	0.01
Fe	2.77	2.74	2.79	2.68	2.88	2.94	2.40	2.41	2.27	2.26	2.03
Mn	0.04	0.05	0.04	0.03	0.03	0.04	0.02	0.03	0.02	0.02	0.01
K	0.11	0.07	0.07	0.06	0.10	0.09	0.05	0.07	0.07	0.07	0.08
Mg	1.39	1.45	1.50	1.63	1.34	1.46	1.97	1.86	1.99	1.96	2.11
Ca	1.95	1.89	1.90	1.90	1.93	1.93	1.93	1.95	1.97	1.96	1.80
Na	0.32	0.35	0.34	0.33	0.33	0.31	0.29	0.30	0.29	0.28	0.43
Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F	0.01	0.01	0.02	0.01	0.03	0.02	0.00	0.01	0.02	0.01	0.03
Fe/Fe+Mg	0.67	0.65	0.65	0.62	0.68	0.67	0.55	0.56	0.53	0.54	0.49

MT98-102 Hornblende (continued)

Sample	HI158	HI159	HI160	HI161	HI162	HI163	HI164	HI184	HI185	HI186	HI187
SiO ₂	42.73	43.57	43.10	47.42	42.69	44.34	43.68	41.88	42.85	40.50	41.11
Al ₂ O ₃	15.74	13.72	14.81	8.71	15.97	11.31	12.58	14.60	13.26	15.38	15.30
TiO ₂	0.58	0.61	0.56	0.44	0.57	0.18	0.35	0.21	0.12	0.19	0.26
Cr ₂ O ₃	0.00	0.07	0.08	0.60	0.00	0.00	0.00	0.04	0.05	0.07	0.06
FeO	15.50	16.81	15.84	14.34	15.00	18.44	18.87	20.94	20.23	20.78	20.17
MnO	0.18	0.12	0.13	0.14	0.13	0.20	0.22	0.21	0.19	0.18	0.11
K ₂ O	0.41	0.47	0.43	0.23	0.42	0.36	0.36	0.51	0.43	0.63	0.58
MgO	9.18	9.16	9.07	12.15	9.34	9.03	8.50	6.64	7.34	6.09	6.44
CaO	11.31	12.20	11.85	12.08	11.24	11.95	11.84	11.87	11.87	11.93	11.80
Na ₂ O	1.39	0.97	1.18	0.69	1.59	0.93	1.11	1.06	0.92	1.15	0.98
CL	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.03	0.00	0.01	0.00
F	0.05	0.02	0.04	0.04	0.04	0.10	0.03	0.17	0.05	0.00	0.01
Total	97.07	97.72	97.09	96.85	96.99	96.84	97.54	98.16	97.31	96.91	96.82

Number of cations in formula based on n oxygens

n	23	23	23	23	23	23	23	23	23	23	23
Si	6.35	6.49	6.42	7.01	6.34	6.71	6.58	6.35	6.51	6.23	6.29
Al iv	1.65	1.51	1.58	0.99	1.66	1.29	1.42	1.65	1.49	1.77	1.71
Al vi	1.11	0.89	1.03	0.53	1.13	0.73	0.81	0.96	0.89	1.02	1.05
Ti	0.06	0.07	0.06	0.05	0.06	0.02	0.04	0.02	0.01	0.02	0.03
Cr	0.00	0.01	0.01	0.07	0.00	0.00	0.00	0.00	0.01	0.01	0.01
Fe	1.93	2.09	1.97	1.77	1.86	2.33	2.38	2.66	2.57	2.67	2.58
Mn	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.02	0.02	0.01
K	0.08	0.09	0.08	0.04	0.08	0.07	0.07	0.10	0.08	0.12	0.11
Mg	2.03	2.03	2.02	2.68	2.07	2.04	1.91	1.50	1.66	1.40	1.47
Ca	1.80	1.95	1.89	1.91	1.79	1.94	1.91	1.93	1.93	1.97	1.94
Na	0.40	0.28	0.34	0.20	0.46	0.27	0.32	0.31	0.27	0.34	0.29
Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F	0.02	0.01	0.02	0.02	0.02	0.05	0.01	0.08	0.02	0.00	0.00
Fe/Fe+Mg	0.49	0.51	0.49	0.40	0.47	0.53	0.55	0.64	0.61	0.66	0.64

MT98-102 Hornblende (continued)

Sample	H188	H189	H190	H191	H192	H193	H194	H195	H196	H197	H198
SiO ₂	42.03	41.76	39.18	40.22	36.70	37.30	41.05	42.60	41.84	41.90	37.18
Al ₂ O ₃	14.44	14.42	14.82	13.95	23.70	23.44	12.89	11.67	12.39	12.26	26.62
TiO ₂	0.17	0.14	0.17	0.08	0.06	0.10	0.07	0.08	0.33	0.36	0.10
Cr ₂ O ₃	0.04	0.00	0.05	0.03	0.02	0.01	0.00	0.06	0.02	0.07	0.07
FeO	19.66	20.57	21.36	21.32	11.30	12.19	22.08	20.62	18.73	18.85	7.72
MnO	0.19	0.21	0.30	0.22	0.11	0.14	0.34	0.28	0.28	0.25	0.06
K ₂ O	0.49	0.57	0.58	0.56	0.01	0.02	0.45	0.38	0.40	0.42	0.00
MgO	6.90	7.06	6.14	6.55	0.00	0.00	7.14	8.11	8.34	8.11	0.07
CaO	12.06	11.96	11.63	11.69	23.34	23.07	11.52	11.76	11.86	11.91	23.96
Na ₂ O	1.05	0.99	0.98	1.04	0.00	0.00	0.96	0.77	0.89	0.87	0.01
CL	0.02	0.01	0.09	0.05	0.01	0.00	0.03	0.03	0.02	0.00	0.01
F	0.02	0.01	0.08	0.13	0.06	0.11	0.07	0.00	0.01	0.16	0.20
Total	97.07	97.70	95.52	96.11	95.54	96.56	96.73	96.56	95.24	95.46	96.48

Number of cations in formula based on n oxygens

n	23	23	23	23	23	23	23	23	23	23	23
Si	6.40	6.35	6.17	6.29	5.63	5.67	6.38	6.57	6.49	6.51	5.55
Al iv	1.60	1.65	1.83	1.71	2.37	2.33	1.62	1.43	1.51	1.49	2.45
Al vi	0.99	0.93	0.93	0.87	1.91	1.87	0.74	0.69	0.76	0.75	2.24
Ti	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.04	0.04	0.01
Cr	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01
Fe	2.50	2.62	2.81	2.79	1.45	1.55	2.87	2.66	2.43	2.45	0.96
Mn	0.02	0.03	0.04	0.03	0.01	0.02	0.04	0.04	0.04	0.03	0.01
K	0.10	0.11	0.12	0.11	0.00	0.00	0.09	0.08	0.08	0.08	0.00
Mg	1.57	1.60	1.44	1.53	0.00	0.00	1.65	1.86	1.93	1.88	0.02
Ca	1.97	1.95	1.96	1.96	3.83	3.76	1.92	1.94	1.97	1.98	3.83
Na	0.31	0.29	0.30	0.31	0.00	0.00	0.29	0.23	0.27	0.26	0.00
Cl	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F	0.01	0.00	0.04	0.06	0.03	0.05	0.03	0.00	0.01	0.08	0.09
Fe/Fe+Mg	0.62	0.62	0.66	0.65	1.00	1.00	0.63	0.59	0.56	0.57	0.98

MT98-102 Hornblende (continued)

Sample	H199	H200	H201	H202	H203	H204	H205	H206	H207	H208	H209
SiO ₂	37.42	36.46	36.72	38.30	38.96	37.57	37.66	42.54	41.06	39.80	40.31
Al ₂ O ₃	27.39	23.29	23.08	15.24	15.17	28.42	28.17	12.29	14.11	15.14	15.33
TiO ₂	0.18	0.10	0.10	0.14	0.16	0.19	0.15	0.26	0.43	0.56	0.61
Cr ₂ O ₃	0.05	0.01	0.05	0.07	0.04	0.04	0.08	0.00	0.07	0.03	0.13
FeO	7.27	12.03	12.70	21.70	21.49	5.72	6.69	19.06	18.56	18.88	18.96
MnO	0.05	0.07	0.13	0.24	0.20	0.15	0.23	0.17	0.15	0.28	0.14
K ₂ O	0.02	0.01	0.00	0.47	0.58	0.01	0.01	0.39	0.46	0.42	0.45
MgO	0.08	0.02	0.01	6.01	6.08	0.05	0.04	8.57	7.94	7.21	7.61
CaO	23.87	23.31	23.41	11.81	11.72	23.91	23.55	11.87	11.54	11.60	11.79
Na ₂ O	0.00	0.00	0.00	0.94	0.93	0.00	0.05	0.92	1.11	1.08	1.04
CL	0.00	0.02	0.01	0.03	0.01	0.03	0.00	0.00	0.04	0.01	0.00
F	0.06	0.08	0.06	0.36	0.19	0.06	0.02	0.24	0.08	0.20	0.22
Total	97.01	95.41	96.51	95.33	95.55	96.60	96.84	96.52	95.80	95.40	96.89

Number of cations in formula based on n oxygens

n	23	23	23	23	23	23	23	23	23	23	23
Si	5.54	5.61	5.62	6.07	6.13	5.53	5.53	6.53	6.34	6.19	6.18
Al iv	2.46	2.39	2.38	1.93	1.87	2.47	2.47	1.47	1.66	1.81	1.82
Al vi	2.31	1.84	1.78	0.92	0.95	2.45	2.41	0.75	0.90	0.97	0.95
Ti	0.02	0.01	0.01	0.02	0.02	0.02	0.02	0.03	0.05	0.07	0.07
Cr	0.01	0.00	0.01	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.02
Fe	0.90	1.55	1.62	2.88	2.83	0.70	0.82	2.45	2.40	2.46	2.43
Mn	0.01	0.01	0.02	0.03	0.03	0.02	0.03	0.02	0.02	0.04	0.02
K	0.00	0.00	0.00	0.10	0.12	0.00	0.00	0.08	0.09	0.08	0.09
Mg	0.02	0.00	0.00	1.42	1.43	0.01	0.01	1.96	1.83	1.67	1.74
Ca	3.78	3.84	3.84	2.01	1.98	3.77	3.71	1.95	1.91	1.93	1.94
Na	0.00	0.00	0.00	0.29	0.28	0.00	0.01	0.28	0.33	0.33	0.31
Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F	0.03	0.04	0.03	0.18	0.09	0.03	0.01	0.12	0.04	0.10	0.11
Fe/Fe+Mg	0.98	1.00	1.00	0.67	0.66	0.99	0.99	0.56	0.57	0.59	0.58

MT98-102 Hornblende (continued)

Sample	H210	H211	H212	H213	H214	H215	H216	H217	H218	H222	H223
SiO ₂	39.90	39.30	39.97	39.93	40.41	41.64	38.93	40.70	49.60	40.89	41.24
Al ₂ O ₃	14.48	14.70	14.17	13.03	14.41	13.43	14.56	14.50	21.30	15.45	15.54
TiO ₂	0.18	0.09	0.28	0.33	0.17	0.19	0.18	0.20	0.11	0.46	0.44
Cr ₂ O ₃	0.05	0.04	0.08	0.00	0.05	0.12	0.00	0.07	0.00	0.12	0.33
FeO	21.38	21.60	21.88	22.01	21.03	21.04	21.74	19.74	6.79	19.01	18.72
MnO	0.19	0.23	0.25	0.24	0.31	0.25	0.33	0.33	0.14	0.17	0.21
K ₂ O	0.47	0.50	0.48	0.49	0.44	0.31	0.57	0.34	0.96	0.59	0.51
MgO	6.54	5.88	6.10	6.70	6.18	6.75	6.08	6.63	2.67	6.98	7.49
CaO	11.79	11.84	12.00	11.62	11.66	11.47	12.05	11.32	9.85	11.53	11.28
Na ₂ O	0.93	0.98	0.99	0.97	1.01	0.98	1.01	1.12	3.12	1.05	0.95
CL	0.00	0.01	0.02	0.02	0.02	0.01	0.00	0.00	0.00	0.00	0.01
F	0.17	0.13	0.15	0.24	0.30	0.17	0.19	0.08	0.22	0.27	0.04
Total	96.38	95.57	96.47	95.76	96.10	96.42	95.81	95.28	95.10	96.71	97.19

Number of cations in formula based on n oxygens

n	23	23	23	23	23	23	23	23	23	23	23
Si	6.23	6.20	6.24	6.30	6.30	6.44	6.15	6.35	7.09	6.26	6.27
Al iv	1.77	1.80	1.76	1.70	1.70	1.56	1.85	1.65	0.91	1.74	1.73
Al vi	0.89	0.94	0.85	0.73	0.95	0.88	0.86	1.01	2.67	1.05	1.05
Ti	0.02	0.01	0.03	0.04	0.02	0.02	0.02	0.02	0.01	0.05	0.05
Cr	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.01	0.00	0.01	0.04
Fe	2.79	2.85	2.86	2.91	2.74	2.72	2.87	2.57	0.81	2.44	2.38
Mn	0.03	0.03	0.03	0.03	0.04	0.03	0.04	0.04	0.02	0.02	0.03
K	0.09	0.10	0.10	0.10	0.09	0.06	0.12	0.07	0.17	0.12	0.10
Mg	1.52	1.38	1.42	1.58	1.44	1.56	1.43	1.54	0.57	1.59	1.70
Ca	1.97	2.00	2.01	1.97	1.95	1.90	2.04	1.89	1.51	1.89	1.84
Na	0.28	0.30	0.30	0.30	0.30	0.29	0.31	0.34	0.86	0.31	0.28
Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F	0.08	0.06	0.07	0.12	0.15	0.08	0.09	0.04	0.10	0.13	0.02
Fe/Fe+Mg	0.65	0.67	0.67	0.65	0.66	0.64	0.67	0.63	0.59	0.60	0.58

MT98-102 Hornblende (continued)

Sample	H228	H229	H232	H235
SiO ₂	50.31	51.05	40.82	36.29
Al ₂ O ₃	28.79	29.54	15.54	17.60
TiO ₂	0.06	0.03	0.41	1.67
Cr ₂ O ₃	0.06	0.01	0.06	0.14
FeO	1.23	7.52	18.93	18.66
MnO	0.10	0.00	0.15	0.14
K ₂ O	0.36	0.32	0.52	8.93
MgO	0.77	3.31	7.12	11.37
CaO	11.07	11.84	11.98	0.08
Na ₂ O	3.76	2.79	1.17	0.00
CL	0.03	0.00	0.01	0.02
F	0.21	0.00	0.11	0.09
Total	96.86	106.6	96.9	95.37

Number of cations in formula based on n oxygens

n	23	23	23	23
Si	6.82	6.48	6.23	5.76
Al ^{iv}	1.18	1.52	1.77	2.24
Al ^{vi}	3.42	2.90	1.03	1.06
Ti	0.01	0.00	0.05	0.20
Cr	0.01	0.00	0.01	0.02
Fe	0.14	0.80	2.42	2.48
Mn	0.01	0.00	0.02	0.02
K	0.06	0.05	0.10	1.81
Mg	0.16	0.63	1.62	2.69
Ca	1.61	1.61	1.96	0.01
Na	0.99	0.69	0.35	0.00
Cl	0.00	0.00	0.00	0.00
F	0.09	0.00	0.05	0.05
Fe/Fe+Mg	0.47	0.56	0.60	0.48

MT98-102 Plagioclase

Sample	P28	P29	P30	P31	P32	P33	P34	P35	P36	P37	P38
SiO ₂	61.70	52.73	61.17	63.24	55.27	59.50	53.60	54.17	54.82	58.15	53.78
Al ₂ O ₃	24.49	30.48	25.09	23.80	29.03	26.58	29.46	29.75	29.19	26.73	30.70
K ₂ O	0.09	0.04	0.08	0.09	0.16	0.03	0.05	0.05	0.04	0.06	0.04
CaO	5.96	13.03	6.58	4.97	10.67	8.12	11.79	11.75	11.49	8.69	12.77
Na ₂ O	8.03	4.19	7.96	8.81	5.28	7.07	4.80	4.67	5.02	6.71	4.17
FeO	0.32	0.30	0.16	0.11	0.47	0.22	0.44	0.39	0.27	0.17	0.44
SrO	-	-	-	-	-	-	-	-	-	-	-
BaO	-	-	-	-	-	-	-	-	-	-	-
Total	100.59	100.77	101.04	101.02	100.88	101.52	100.14	100.78	100.83	100.51	101.90

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.72	2.37	2.69	2.77	2.47	2.62	2.42	2.43	2.45	2.59	2.39
Al	1.27	1.62	1.30	1.23	1.53	1.38	1.57	1.57	1.54	1.40	1.61
K	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Ca	0.28	0.63	0.31	0.23	0.51	0.38	0.57	0.56	0.55	0.41	0.61
Na	0.69	0.37	0.68	0.75	0.46	0.60	0.42	0.41	0.44	0.58	0.36
Fe	0.01	0.01	0.01	0.00	0.02	0.01	0.02	0.01	0.01	0.01	0.02
Sr	-	-	-	-	-	-	-	-	-	-	-
Ba	-	-	-	-	-	-	-	-	-	-	-
% Ab	70.5	36.7	68.3	75.8	46.8	61.1	42.3	41.7	44.1	58.1	37.1
% An	28.9	63.1	31.2	23.6	52.3	38.8	57.4	58.0	55.7	41.6	62.7
% Or	0.5	0.2	0.5	0.5	0.9	0.2	0.3	0.3	0.2	0.3	0.2

Sample	P39	P40	P41	P42	P43	P44	P59	P60	P61	P62	P63
SiO ₂	55.82	55.20	54.69	53.89	53.94	53.75	52.57	54.39	56.60	61.28	56.75
Al ₂ O ₃	29.11	29.35	28.44	29.42	30.07	29.78	29.89	29.71	27.13	24.45	27.37
K ₂ O	0.05	0.04	0.05	0.03	0.03	0.04	0.03	0.04	0.03	0.04	0.04
CaO	11.08	11.49	10.65	11.86	12.10	12.00	12.38	11.96	9.73	6.40	9.85
Na ₂ O	5.26	5.01	5.33	4.79	4.60	4.49	4.00	4.87	6.06	8.10	6.10
FeO	0.31	0.36	0.39	0.35	0.43	0.35	0.49	0.43	0.11	0.12	0.29
SrO	-	-	-	-	-	-	-	-	-	-	-
BaO	-	-	-	-	-	-	-	-	-	-	-
Total	101.63	101.45	99.55	100.34	101.17	100.41	99.36	101.40	99.66	100.39	100.40

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[illegible]

MT98-102 Plagioclase (continued)

Sample	P64	P65	P66	P96	P97	P98	P99	P100	P101	P102	P103
SiO ₂	62.32	61.23	65.41	57.64	56.81	54.95	51.25	52.03	53.69	55.93	59.78
Al ₂ O ₃	23.98	24.82	22.24	27.82	28.76	29.78	32.29	31.56	30.24	28.67	26.70
K ₂ O	0.03	0.04	0.06	0.10	0.09	0.08	0.06	0.07	0.07	0.09	0.10
CaO	5.57	6.66	3.52	9.19	10.26	11.36	14.29	13.60	12.17	10.18	7.71
Na ₂ O	8.59	8.04	9.99	5.05	5.55	5.33	3.44	4.05	4.71	5.90	7.12
FeO	0.17	0.30	0.19	0.17	0.26	0.24	0.28	0.11	0.12	0.34	0.00
SrO	-	-	-	-	-	-	-	-	-	-	-
BaO	-	-	-	-	-	-	-	-	-	-	-
Total	100.66	101.09	101.41	99.97	101.73	101.74	101.61	101.42	101.00	101.11	101.41

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.75	2.70	2.85	2.57	2.51	2.44	2.30	2.33	2.41	2.49	2.63
Al	1.25	1.29	1.14	1.46	1.50	1.56	1.71	1.67	1.60	1.51	1.38
K	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.01
Ca	0.26	0.31	0.16	0.44	0.49	0.54	0.69	0.65	0.58	0.49	0.36
Na	0.73	0.69	0.84	0.44	0.48	0.46	0.30	0.35	0.41	0.51	0.61
Fe	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.00
Sr	-	-	-	-	-	-	-	-	-	-	-
Ba	-	-	-	-	-	-	-	-	-	-	-
%Ab	73.5	68.4	83.4	49.5	49.2	45.7	30.2	34.9	41.0	50.9	62.2
%An	26.3	31.3	16.2	49.8	50.3	53.8	69.4	64.7	58.6	48.6	37.2
%Or	0.2	0.2	0.3	0.6	0.5	0.5	0.3	0.4	0.4	0.5	0.6

MT98-102 Plagioclase (continued)

Sample	P104	P105	P106	P138	P139	P140	102P 141	P145	P146	P147	P148
SiO ₂	55.01	63.09	56.78	62.46	59.31	60.48	61.45	60.65	61.64	62.08	60.68
Al ₂ O ₃	29.25	24.78	28.49	24.26	26.20	25.82	24.83	25.55	25.59	25.31	26.03
K ₂ O	0.11	0.09	0.09	0.04	0.05	0.02	0.05	0.08	0.04	0.09	0.04
CaO	11.21	5.51	9.91	5.62	7.70	7.17	6.15	6.71	6.72	6.42	7.29
Na ₂ O	5.53	8.03	6.06	8.79	7.39	7.72	8.31	7.88	7.88	8.04	7.52
FeO	0.00	0.00	0.00	0.27	0.57	0.40	0.33	0.44	0.38	0.21	0.22
SrO	-	-	-	-	-	-	-	-	-	-	-
BaO	-	-	-	-	-	-	-	-	-	-	-
Total	101.11	101.50	101.33	101.44	101.22	101.61	101.12	101.31	102.25	102.15	101.78

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.46	2.75	2.52	2.74	2.62	2.66	2.70	2.67	2.68	2.70	2.66
Al	1.54	1.27	1.49	1.25	1.37	1.34	1.29	1.33	1.31	1.30	1.34
K	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ca	0.54	0.26	0.47	0.26	0.36	0.34	0.29	0.32	0.31	0.30	0.34
Na	0.48	0.68	0.52	0.75	0.63	0.66	0.71	0.67	0.67	0.68	0.64
Fe	0.00	0.00	0.00	0.01	0.02	0.01	0.01	0.02	0.01	0.01	0.01
Sr	-	-	-	-	-	-	-	-	-	-	-
Ba	-	-	-	-	-	-	-	-	-	-	-
%Ab	46.9	72.1	52.3	73.7	63.3	66.0	70.8	67.7	67.8	69.0	65.0
%An	52.5	27.3	47.2	26.0	36.4	33.9	28.9	31.9	32.0	30.5	34.8
%Or	0.6	0.5	0.5	0.2	0.3	0.1	0.3	0.5	0.2	0.5	0.2

MT98-102 Plagioclase (continued)

Sample	P149	P150	P151	P152	P153	P154	P155	P156	P190	P191	P192
SiO ₂	63.90	63.52	60.32	63.94	61.83	64.43	64.24	62.74	55.72	54.41	55.92
Al ₂ O ₃	24.11	23.86	26.59	23.43	25.63	23.22	24.31	24.84	30.18	30.50	29.31
K ₂ O	0.07	0.09	0.07	0.09	0.07	0.09	0.07	0.04	0.03	0.06	0.02
CaO	4.86	4.93	7.94	4.56	6.61	4.06	5.14	5.70	11.97	12.25	11.17
Na ₂ O	9.05	9.10	7.25	9.29	7.25	9.47	9.00	8.61	3.58	4.57	5.51
FeO	0.23	0.06	0.27	0.14	0.18	0.05	0.19	0.13	0.62	0.47	0.47
SrO	-	-	-	-	-	-	-	-	-	-	-
BaO	-	-	-	-	-	-	-	-	-	-	-
Total	102.22	101.56	102.44	101.45	101.57	101.32	102.95	102.06	102.10	102.26	102.40

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.77	2.77	2.63	2.79	2.70	2.81	2.76	2.73	2.45	2.41	2.47
Al	1.23	1.23	1.37	1.20	1.32	1.19	1.23	1.27	1.57	1.59	1.52
K	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Ca	0.23	0.23	0.37	0.21	0.31	0.19	0.24	0.27	0.56	0.58	0.53
Na	0.76	0.77	0.61	0.79	0.61	0.80	0.75	0.73	0.31	0.39	0.47
Fe	0.01	0.00	0.01	0.01	0.01	0.00	0.01	0.00	0.02	0.02	0.02
Sr	-	-	-	-	-	-	-	-	-	-	-
Ba	-	-	-	-	-	-	-	-	-	-	-
%Ab	76.8	76.6	62.1	78.3	66.2	80.4	75.7	73.1	35.0	40.2	47.1
%An	22.8	22.9	37.6	21.2	33.4	19.1	23.9	26.7	64.8	59.5	52.8
%Or	0.4	0.5	0.4	0.5	0.4	0.5	0.4	0.2	0.2	0.3	0.1

MT98-102 Plagioclase (continued)

Sample	P193	P194	P195	P196	P197	P198	P199	P200	P201	P202	P203
SiO ₂	53.83	57.52	55.95	50.90	42.11	52.95	51.04	51.58	51.18	52.91	52.28
Al ₂ O ₃	30.50	28.41	29.02	30.82	21.68	28.92	29.98	29.62	30.44	29.04	29.03
K ₂ O	0.04	0.05	0.05	0.01	0.44	0.10	0.06	0.04	0.06	0.07	0.05
CaO	12.93	10.12	10.95	13.35	12.77	11.12	12.86	12.24	13.14	11.62	11.61
Na ₂ O	4.20	6.06	5.54	3.57	1.85	4.77	4.34	4.33	4.03	4.62	4.69
FeO	0.41	0.44	0.47	0.31	13.65	0.31	0.29	0.25	0.32	0.25	0.22
SrO	-	-	-	0.03	0.00	0.04	0.02	0.07	0.00	0.01	0.03
BaO	-	-	-	0.00	0.00	0.00	0.11	0.00	0.15	0.15	0.00
Total	101.91	102.60	101.98	99.00	92.49	98.22	98.70	98.13	99.32	98.67	97.91

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.39	2.52	2.48	2.34	2.25	2.44	2.36	2.38	2.35	2.43	2.42
Al	1.60	1.47	1.51	1.67	1.37	1.57	1.63	1.61	1.65	1.57	1.58
K	0.00	0.00	0.00	0.00	0.03	0.01	0.00	0.00	0.00	0.00	0.00
Ca	0.62	0.48	0.52	0.66	0.73	0.55	0.64	0.61	0.65	0.57	0.58
Na	0.36	0.52	0.48	0.32	0.19	0.43	0.39	0.39	0.36	0.41	0.42
Fe	0.02	0.02	0.02	0.01	0.61	0.01	0.01	0.01	0.01	0.01	0.01
Sr	-	-	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	-	-	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
%Ab	36.9	51.9	47.7	32.6	20.1	43.4	37.8	38.9	35.6	41.7	42.1
%An	62.8	47.9	52.1	67.3	76.7	56.0	61.9	60.9	64.1	57.9	57.6
%Or	0.2	0.3	0.3	0.1	3.1	0.6	0.4	0.2	0.3	0.4	0.3

MT98-102 Plagioclase (continued)

Sample	P204	P205	P206	P207	P208	P209	P210	P211	P212	P213	P214
SiO ₂	53.34	55.91	58.75	53.15	54.27	54.31	55.59	51.67	50.66	50.04	58.36
Al ₂ O ₃	28.29	26.45	23.90	28.03	27.48	27.75	26.50	29.35	29.62	30.44	24.70
K ₂ O	0.03	0.06	0.07	0.06	0.04	0.11	0.10	0.04	0.11	0.05	0.03
CaO	10.67	8.45	6.10	10.35	9.78	10.27	8.44	11.60	12.10	12.97	7.01
Na ₂ O	5.25	6.42	7.78	5.00	5.88	5.65	6.69	4.57	4.25	3.94	7.29
FeO	0.16	0.28	0.11	0.37	0.25	0.40	0.34	0.58	0.28	0.25	0.24
SrO	0.00	0.08	0.00	0.00	0.05	0.01	0.04	0.05	0.05	0.01	0.00
BaO	0.24	0.00	0.00	0.06	0.00	0.04	0.06	0.02	0.00	0.11	0.00
Total	97.97	97.66	96.71	97.02	97.74	98.54	97.77	97.89	97.06	97.80	97.64

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.46	2.57	2.70	2.47	2.50	2.49	2.56	2.39	2.37	2.33	2.67
Al	1.54	1.43	1.30	1.54	1.49	1.50	1.44	1.60	1.63	1.67	1.33
K	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.00	0.00
Ca	0.53	0.42	0.30	0.52	0.48	0.50	0.42	0.58	0.61	0.65	0.34
Na	0.47	0.57	0.69	0.45	0.53	0.50	0.60	0.41	0.39	0.36	0.65
Fe	0.01	0.01	0.00	0.01	0.01	0.02	0.01	0.02	0.01	0.01	0.01
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
%Ab	47.0	57.7	69.5	46.4	52.0	49.6	58.6	41.5	38.6	35.4	65.2
%An	52.8	41.9	30.1	53.2	47.8	49.8	40.8	58.2	60.7	64.4	34.6
%Or	0.2	0.3	0.4	0.4	0.2	0.6	0.6	0.2	0.6	0.3	0.2

MT98-102 Plagioclase (continued)

Sample	P215	P216	P217	P218	P219	P220	P221	P222	P223	P224	P225
SiO ₂	60.22	62.53	59.10	58.56	56.12	57.38	58.97	59.20	55.90	55.12	54.14
Al ₂ O ₃	23.85	22.40	24.25	24.42	23.70	25.68	24.78	23.99	26.64	27.11	27.83
K ₂ O	0.05	0.09	0.10	0.10	0.05	0.03	0.06	0.06	0.03	0.04	0.07
CaO	5.54	3.65	6.22	5.21	5.93	7.48	6.25	5.87	8.59	9.34	10.04
Na ₂ O	7.97	8.95	7.82	7.74	7.50	7.01	7.51	7.82	6.29	6.02	5.49
FeO	0.15	0.12	0.23	0.15	0.17	0.40	0.09	0.13	0.51	0.47	0.44
SrO	0.08	0.07	0.00	0.03	0.02	0.00	0.05	0.00	0.08	0.09	0.04
BaO	0.17	0.00	0.00	0.17	0.00	0.04	0.19	0.09	0.00	0.00	0.11
Total	98.03	97.81	97.71	96.38	93.49	98.03	97.91	97.14	98.05	98.18	98.17

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.73	2.82	2.69	2.70	2.67	2.62	2.68	2.71	2.56	2.53	2.49
Al	1.27	1.19	1.30	1.33	1.33	1.38	1.33	1.29	1.44	1.47	1.51
K	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ca	0.27	0.18	0.30	0.26	0.30	0.37	0.30	0.29	0.42	0.46	0.49
Na	0.70	0.78	0.69	0.69	0.69	0.62	0.66	0.69	0.56	0.54	0.49
Fe	0.01	0.00	0.01	0.01	0.01	0.02	0.00	0.01	0.02	0.02	0.02
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
%Ab	72.0	81.2	69.1	72.5	69.4	62.8	68.2	70.4	56.9	53.7	49.5
%An	27.7	18.3	30.4	26.9	30.3	37.0	31.4	29.2	42.9	46.1	50.0
%Or	0.3	0.5	0.6	0.6	0.3	0.2	0.4	0.3	0.2	0.2	0.4

MT98-102 Plagioclase (continued)

Sample	P226	P227	P228	P229	P230	P231	P232	P233	P234	P235	P236
SiO ₂	54.01	54.92	51.10	42.38	48.40	48.62	51.83	49.32	52.89	43.27	54.50
Al ₂ O ₃	27.95	27.52	28.43	25.44	31.79	31.55	28.09	28.39	29.26	26.08	28.54
K ₂ O	0.08	0.04	0.04	0.30	0.04	0.04	0.18	0.09	0.08	0.08	0.07
CaO	10.40	9.73	11.40	13.95	14.94	14.54	11.03	11.52	10.62	8.53	10.08
Na ₂ O	5.52	5.84	4.64	1.08	3.03	3.14	5.37	3.89	5.24	4.94	5.74
FeO	0.34	0.35	0.37	12.38	0.38	0.47	2.65	4.57	2.16	9.60	0.41
SrO	0.07	0.00	0.05	0.01	0.04	0.00	0.00	0.05	0.00	0.00	0.06
BaO	0.00	0.00	0.00	0.13	0.00	0.04	0.19	0.04	0.00	0.06	0.04
Total	98.37	98.40	96.04	95.68	98.62	98.40	99.34	97.87	100.26	92.57	99.46

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.48	2.51	2.41	2.17	2.25	2.26	2.40	2.34	2.41	2.24	2.47
Al	1.51	1.48	1.58	1.53	1.74	1.73	1.53	1.59	1.57	1.59	1.53
K	0.00	0.00	0.00	0.02	0.00	0.00	0.01	0.01	0.00	0.01	0.00
Ca	0.51	0.48	0.58	0.77	0.74	0.72	0.55	0.58	0.52	0.47	0.49
Na	0.49	0.52	0.42	0.11	0.27	0.28	0.48	0.36	0.46	0.50	0.51
Fe	0.01	0.01	0.01	0.53	0.01	0.02	0.10	0.18	0.08	0.42	0.02
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Ab	48.8	51.9	42.3	12.0	26.8	28.0	46.4	37.7	47.0	50.9	50.5
% An	50.8	47.8	57.4	85.8	73.0	71.7	52.6	61.7	52.6	48.6	49.1
% Or	0.4	0.3	0.2	2.2	0.2	0.3	1.0	0.6	0.5	0.6	0.4

MT98-102 Plajase (continued)

Sample	P237	P238	P239	P240	P241	P242	P243	P244	P245	P246	P247
SiO ₂	46.51	46.01	46.12	46.18	54.70	53.93	53.95	33.08	48.78	50.16	52.81
Al ₂ O ₃	21.71	27.11	27.07	25.84	28.87	28.74	28.66	22.57	32.27	31.97	30.69
K ₂ O	0.42	0.03	0.02	0.05	0.05	0.05	0.06	2.67	0.81	0.09	0.07
CaO	11.30	16.02	15.86	10.32	11.05	8.94	10.32	4.78	12.78	14.40	12.82
Na ₂ O	3.46	3.33	3.33	5.01	5.49	5.67	5.66	0.38	3.05	3.26	4.42
FeO	9.06	4.29	4.01	3.67	0.53	3.76	1.06	19.44	1.70	0.34	0.22
SrO	0.00	0.00	0.00	0.04	0.02	0.00	0.03	0.00	0.00	0.00	0.06
BaO	0.00	0.09	0.00	0.00	0.17	0.00	0.00	0.02	0.43	0.00	0.00
Total	92.45	96.88	96.42	91.13	100.87	101.07	99.74	82.94	99.83	100.21	101.08

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.41	2.25	2.25	2.35	2.46	2.44	2.45	2.04	2.25	2.28	2.37
Al	1.32	1.56	1.56	1.55	1.53	1.53	1.53	1.64	1.76	1.71	1.62
K	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.05	0.01	0.00
Ca	0.63	0.84	0.83	0.56	0.53	0.43	0.50	0.32	0.63	0.70	0.62
Na	0.35	0.32	0.32	0.50	0.48	0.50	0.50	0.05	0.27	0.29	0.38
Fe	0.39	0.18	0.16	0.16	0.02	0.14	0.04	1.00	0.07	0.01	0.01
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
% Ab	34.7	27.3	27.5	46.7	47.2	53.3	49.7	8.0	28.7	28.9	38.3
% An	62.6	72.5	72.4	53.1	52.5	46.4	50.0	55.3	66.3	70.6	61.3
% Or	2.7	0.2	0.1	0.3	0.3	0.3	0.3	36.7	5.0	0.5	0.4

MT98-102 Plagioclase (continued)

Sample	P248	P249	P250	P251	P252	P253	P254	P255	P256	P257	P258
SiO ₂	40.85	44.64	41.82	47.05	58.78	64.09	59.41	59.48	58.62	57.92	62.42
Al ₂ O ₃	32.85	35.38	30.55	34.96	22.73	22.66	25.83	25.86	26.48	27.03	24.98
K ₂ O	0.12	0.29	2.41	0.05	0.16	0.07	0.07	0.07	0.05	0.06	0.08
CaO	17.04	17.40	13.18	17.70	5.71	3.63	7.26	7.33	8.06	8.29	5.62
Na ₂ O	1.01	1.07	0.92	1.57	7.86	9.76	7.55	7.43	7.26	6.99	8.68
FeO	3.74	0.96	5.38	0.23	2.84	0.31	0.12	0.08	0.25	0.19	0.08
SrO	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00
BaO	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	95.73	99.74	94.29	101.57	98.09	100.52	100.25	100.29	100.72	100.48	101.86

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.01	2.07	2.11	2.13	2.70	2.82	2.64	2.65	2.61	2.58	2.72
Al	1.91	1.93	1.82	1.87	1.23	1.17	1.36	1.36	1.39	1.42	1.28
K	0.01	0.02	0.16	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Ca	0.90	0.86	0.71	0.86	0.28	0.17	0.35	0.35	0.38	0.40	0.26
Na	0.10	0.10	0.09	0.14	0.70	0.83	0.65	0.64	0.63	0.60	0.73
Fe	0.15	0.04	0.23	0.01	0.11	0.01	0.00	0.00	0.01	0.01	0.00
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
%Ab	9.6	9.8	9.4	13.8	70.6	82.6	65.0	64.4	61.8	60.2	73.3
%An	89.6	88.4	74.4	85.9	28.4	17.0	34.6	35.2	37.9	39.5	26.2
%Or	0.8	1.8	16.2	0.3	1.0	0.4	0.4	0.4	0.3	0.3	0.4

MT98-102 Plagioclase (continued)

Sample	P259	P260	P261	P262	P263	P264	P265	P266	P267	P268	P269
SiO ₂	61.98	55.65	56.55	57.20	57.42	53.13	53.96	50.11	60.34	56.99	58.60
Al ₂ O ₃	24.50	27.68	27.80	27.17	26.89	30.08	30.18	27.93	25.44	27.76	26.73
K ₂ O	0.24	0.04	0.13	0.12	0.07	0.16	0.05	0.16	0.10	0.10	0.08
CaO	5.18	9.77	8.88	8.20	8.22	11.67	11.45	13.22	6.46	9.38	7.95
Na ₂ O	8.62	6.15	6.53	6.84	6.88	4.80	4.78	4.15	8.11	6.28	7.18
FeO	0.11	0.21	0.12	0.14	0.09	0.58	0.20	1.81	0.12	0.22	0.12
SrO	0.00	0.00	0.03	0.08	0.03	0.00	0.03	0.00	0.00	0.04	0.00
BaO	0.11	0.11	0.00	0.00	0.00	0.26	0.00	0.15	0.04	0.13	0.00
Total	100.73	99.61	100.06	99.75	99.59	100.69	100.63	97.54	100.60	100.90	100.67

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.73	2.52	2.54	2.57	2.58	2.40	2.42	2.37	2.67	2.54	2.60
Al	1.27	1.48	1.47	1.44	1.42	1.60	1.60	1.55	1.33	1.46	1.40
K	0.01	0.00	0.01	0.01	0.00	0.01	0.00	0.01	0.01	0.01	0.00
Ca	0.24	0.47	0.43	0.39	0.40	0.56	0.55	0.67	0.31	0.45	0.38
Na	0.74	0.54	0.57	0.60	0.60	0.42	0.42	0.38	0.70	0.54	0.62
Fe	0.00	0.01	0.00	0.01	0.00	0.02	0.01	0.07	0.00	0.01	0.00
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Ab	74.1	53.1	56.7	59.7	60.0	42.3	42.9	35.9	69.1	54.5	61.7
% An	24.6	46.7	42.6	39.6	39.6	56.8	56.8	63.2	30.4	44.9	37.8
% Or	1.4	0.2	0.8	0.7	0.4	1.0	0.3	0.9	0.5	0.6	0.5

MT98-102 Plagioclase (continued)

Sample	P270	P271	P272	P273	P274	P275	P276	P277	P278	P279	P280
SiO ₂	58.58	64.06	64.03	63.14	64.89	64.64	56.82	59.27	57.80	64.92	62.92
Al ₂ O ₃	26.51	22.85	23.09	23.18	22.28	22.22	27.13	26.02	26.46	22.26	23.87
K ₂ O	0.39	0.08	0.07	0.09	0.11	0.13	0.07	0.06	0.05	0.06	0.07
CaO	7.38	3.63	3.80	4.30	3.04	3.02	9.02	7.62	8.04	2.98	4.88
Na ₂ O	7.00	9.73	9.62	9.33	10.10	9.86	6.61	7.37	6.99	9.99	8.96
FeO	0.26	0.14	0.04	0.07	0.05	0.10	0.22	0.08	0.00	0.06	0.12
SrO	0.00	0.00	0.00	0.05	0.00	0.03	0.00	0.00	0.05	0.03	0.02
BaO	0.11	0.21	0.00	0.00	0.19	0.09	0.00	0.00	0.04	0.00	0.02
Total	100.22	100.70	100.65	100.16	100.67	100.08	99.87	100.42	99.44	100.31	100.85

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.62	2.82	2.81	2.79	2.85	2.85	2.56	2.63	2.60	2.85	2.76
Al	1.39	1.18	1.19	1.21	1.15	1.15	1.44	1.36	1.40	1.15	1.24
K	0.02	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
Ca	0.35	0.17	0.18	0.20	0.14	0.14	0.43	0.36	0.39	0.14	0.23
Na	0.61	0.83	0.82	0.80	0.86	0.84	0.58	0.64	0.61	0.85	0.76
Fe	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
%Ab	61.7	82.5	81.8	79.3	85.2	84.9	56.8	63.4	61.0	85.6	76.6
%An	36.0	17.0	17.9	20.2	14.2	14.4	42.8	36.2	38.7	14.1	23.0
%Or	2.3	0.4	0.4	0.5	0.6	0.7	0.4	0.3	0.3	0.3	0.4

MT98-102 Plagioclase (continued)

Sample	P281	P282	P283	P284	P285	P286	P287
SiO ₂	63.69	57.22	57.91	56.22	59.26	60.52	60.14
Al ₂ O ₃	23.08	26.92	26.22	27.76	26.58	25.32	25.34
K ₂ O	0.06	0.20	0.06	0.05	0.07	0.08	0.08
CaO	4.00	9.13	7.95	9.93	7.75	6.57	6.49
Na ₂ O	9.20	6.65	7.20	6.24	7.51	8.02	8.08
FeO	0.08	0.48	0.06	0.13	0.05	0.11	0.05
SrO	0.00	0.04	0.01	0.00	0.02	0.00	0.02
BaO	0.00	0.00	0.00	0.00	0.00	0.30	0.00
Total	100.11	100.64	99.41	100.33	101.23	100.93	100.20

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8
Si	2.81	2.56	2.61	2.52	2.62	2.68	2.67
Al	1.20	1.42	1.39	1.47	1.38	1.32	1.33
K	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Ca	0.19	0.44	0.38	0.48	0.37	0.31	0.31
Na	0.79	0.58	0.63	0.54	0.64	0.69	0.70
Fe	0.00	0.02	0.00	0.00	0.00	0.00	0.00
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.01	0.00
% Ab	80.3	56.2	61.9	53.1	63.4	68.5	69.0
% An	19.3	42.7	37.7	46.6	36.2	31.0	30.6
% Or	0.4	1.1	0.4	0.3	0.4	0.4	0.4

MT98-146 Plagioclase

Sample	P4	P5	P6	P11	P12	P13	P22	P23	P24	P33	P34
SiO ₂	56.93	59.55	60.73	60.66	61.04	61.29	51.61	59.43	60.54	52.98	49.95
Al ₂ O ₃	23.57	24.40	24.21	23.56	23.52	23.70	24.70	25.08	24.71	21.95	22.81
K ₂ O	0.09	0.13	0.07	1.27	0.27	1.44	0.59	0.09	0.08	0.39	0.09
CaO	5.95	6.08	5.75	4.13	4.81	4.47	5.71	6.74	6.06	5.43	4.21
Na ₂ O	8.04	8.01	8.34	8.17	8.58	7.55	7.31	7.84	8.18	4.60	6.32
FeO	0.36	0.25	0.31	0.20	0.17	0.64	1.94	0.39	0.33	1.62	5.80
SrO	0.10	0.09	0.15	0.14	0.08	0.12	0.06	0.14	0.10	0.06	0.05
BaO	0.04	0.00	0.09	0.08	0.00	0.28	0.07	0.05	0.00	0.00	0.00
Total	95.06	98.53	99.65	98.20	98.49	99.49	91.98	99.76	100.01	87.04	89.23

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.68	2.69	2.72	2.75	2.75	2.75	2.55	2.67	2.70	2.71	2.57
Al	1.31	1.30	1.28	1.26	1.25	1.26	1.44	1.33	1.30	1.32	1.38
K	0.01	0.01	0.00	0.07	0.02	0.08	0.04	0.00	0.00	0.03	0.01
Ca	0.30	0.29	0.28	0.20	0.23	0.22	0.30	0.32	0.29	0.30	0.23
Na	0.73	0.70	0.72	0.72	0.75	0.66	0.70	0.68	0.71	0.46	0.63
Fe	0.01	0.01	0.01	0.01	0.01	0.02	0.08	0.01	0.01	0.07	0.25
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
%Ab	70.6	69.9	72.1	72.4	75.1	68.8	67.4	67.5	70.6	58.5	72.6
%An	28.9	29.3	27.5	20.2	23.3	22.5	29.1	32.0	28.9	38.2	26.7
%Or	0.5	0.7	0.4	7.4	1.6	8.6	3.6	0.5	0.5	3.3	0.7

MT98-146 Plagioclase (Continued)

Sample	P35	P36	P37	P64	P65	P66	P67	P89	P91	P96	P97
SiO ₂	61.95	63.48	62.67	62.60	62.50	63.71	62.53	61.87	63.20	63.36	62.67
Al ₂ O ₃	24.12	22.27	22.65	22.49	23.00	22.59	22.53	23.52	22.54	22.42	22.49
K ₂ O	0.07	0.25	0.15	0.08	0.06	0.08	0.09	0.42	0.08	0.07	0.07
CaO	5.34	3.26	3.74	3.47	4.40	3.76	3.69	4.06	3.75	3.67	3.87
Na ₂ O	8.49	9.49	9.48	9.45	9.05	9.77	9.63	9.27	9.52	9.64	9.65
FeO	0.19	0.13	0.06	0.15	0.04	0.09	0.00	0.28	0.06	0.04	0.10
SrO	0.13	0.14	0.07	0.13	0.05	0.11	0.07	0.16	0.10	0.07	0.09
BaO	0.00	0.13	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00
Total	100.30	99.14	98.81	98.38	99.10	100.12	98.60	99.57	99.25	99.26	98.94

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.74	2.83	2.81	2.81	2.79	2.82	2.81	2.76	2.82	2.82	2.81
Al	1.26	1.17	1.19	1.19	1.21	1.18	1.19	1.24	1.18	1.18	1.19
K	0.00	0.01	0.01	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.00
Ca	0.25	0.16	0.18	0.17	0.21	0.18	0.18	0.19	0.18	0.17	0.19
Na	0.73	0.82	0.82	0.82	0.78	0.84	0.84	0.80	0.82	0.83	0.84
Fe	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Ab	73.9	82.8	81.4	82.7	78.6	82.1	82.1	78.6	81.7	82.3	81.5
% An	25.7	15.7	17.8	16.8	21.1	17.5	17.4	19.0	17.8	17.3	18.1
% Or	0.4	1.4	0.8	0.5	0.3	0.4	0.5	2.3	0.4	0.4	0.4

MT98-146 Plagioclase (Continued)

Sample	P98	P129	P130	P133	P134	P135	P136	P147	P148	B151	P152
SiO ₂	63.60	61.69	62.57	62.36	63.31	60.55	60.45	61.59	61.06	60.18	59.77
Al ₂ O ₃	22.81	23.04	22.75	23.14	22.48	24.43	24.06	25.21	24.13	25.25	24.51
K ₂ O	0.07	0.07	0.37	0.10	0.06	0.07	0.07	0.06	0.05	0.07	0.23
CaO	3.69	4.50	3.98	4.34	3.32	5.94	5.38	6.37	5.58	6.52	5.65
Na ₂ O	9.49	9.09	9.04	9.23	9.51	8.38	8.50	8.21	8.71	8.08	8.24
FeO	0.24	0.09	0.00	0.06	0.09	0.11	0.88	0.36	0.23	0.25	0.20
SrO	0.03	0.10	0.17	0.18	0.12	0.15	0.18	0.12	0.07	0.12	0.08
BaO	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.04	0.20	0.00
Total	100.04	98.58	98.89	99.41	98.89	99.62	99.52	101.98	99.87	100.67	98.69

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.81	2.77	2.80	2.78	2.83	2.71	2.71	2.69	2.72	2.67	2.70
Al	1.19	1.22	1.20	1.22	1.18	1.29	1.27	1.30	1.27	1.32	1.30
K	0.00	0.00	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Ca	0.17	0.22	0.19	0.21	0.16	0.28	0.26	0.30	0.27	0.31	0.27
Na	0.81	0.79	0.79	0.80	0.82	0.73	0.74	0.70	0.75	0.70	0.72
Fe	0.01	0.00	0.00	0.00	0.00	0.00	0.03	0.01	0.01	0.01	0.01
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Ab	82.0	78.2	78.7	78.9	83.5	71.6	73.8	69.7	73.7	68.9	71.6
% An	17.6	21.4	19.1	20.5	16.1	28.0	25.8	29.9	26.1	30.7	27.1
% Or	0.4	0.4	2.1	0.6	0.4	0.4	0.4	0.3	0.3	0.4	1.3

MT98-146 Plagioclase (Continued)

Sample	P164	P165	P166	P167	P176	P177	P178	P179	P184	P185	P186
SiO ₂	58.07	58.65	57.88	60.44	60.78	63.04	60.08	59.18	62.69	62.55	62.47
Al ₂ O ₃	25.74	25.46	25.54	23.65	24.57	23.11	24.78	25.12	22.74	22.95	23.25
K ₂ O	0.07	0.08	0.19	1.24	0.06	0.04	0.04	0.17	0.08	0.08	0.07
CaO	7.38	7.05	7.66	4.93	6.12	4.39	6.26	6.44	3.94	4.26	4.51
Na ₂ O	7.59	7.83	7.45	7.89	8.34	9.37	8.21	8.05	9.43	9.16	9.36
FeO	0.48	0.16	0.14	0.82	0.08	0.12	0.09	0.04	0.15	0.14	0.03
SrO	0.15	0.14	0.14	0.08	0.14	0.09	0.17	0.15	0.16	0.14	0.08
BaO	0.03	0.00	0.20	0.00	0.04	0.00	0.00	0.20	0.05	0.13	0.00
Total	99.50	99.36	99.20	99.06	100.13	100.15	99.63	99.34	99.24	99.43	99.77

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.62	2.64	2.62	2.73	2.71	2.79	2.69	2.67	2.80	2.79	2.78
Al	1.37	1.35	1.36	1.26	1.29	1.20	1.31	1.33	1.20	1.21	1.22
K	0.00	0.00	0.01	0.07	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Ca	0.36	0.34	0.37	0.24	0.29	0.21	0.30	0.31	0.19	0.20	0.21
Na	0.66	0.68	0.65	0.69	0.72	0.80	0.71	0.70	0.82	0.79	0.81
Fe	0.02	0.01	0.01	0.03	0.00	0.00	0.00	0.00	0.01	0.01	0.00
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Ab	64.8	66.5	63.1	69.0	70.9	79.2	70.2	68.7	80.9	79.2	78.6
% An	34.8	33.1	35.9	23.8	28.7	20.5	29.6	30.4	18.7	20.4	20.9
% Or	0.4	0.4	1.1	7.1	0.4	0.2	0.2	0.9	0.5	0.5	0.4

MT98-146 Plagioclase (Continued)

Sample	P189	P190	P199	P200	P201	P202	P203	P204	P205	P206	P207
SiO ₂	62.51	63.03	64.76	64.10	64.09	61.80	62.10	59.97	60.87	60.51	61.37
Al ₂ O ₃	22.94	22.83	22.16	22.07	21.08	23.47	23.95	23.86	24.10	23.86	24.30
K ₂ O	0.09	0.06	0.07	0.08	0.18	1.99	0.98	0.62	0.07	1.80	1.49
CaO	4.33	3.98	3.02	3.19	2.31	1.00	0.85	5.28	5.64	2.27	3.68
Na ₂ O	9.18	9.50	10.00	10.18	9.65	8.10	9.22	7.63	7.93	7.44	7.76
FeO	0.04	0.04	0.07	0.07	0.53	0.55	0.35	0.57	0.43	1.44	0.82
SrO	0.07	0.08	0.07	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BaO	0.03	0.00	0.00	0.10	0.01	0.25	0.00	0.00	0.10	0.07	0.13
Total	99.20	99.53	100.16	99.83	97.85	97.15	97.46	97.92	99.13	97.40	99.54

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.79	2.80	2.85	2.84	2.88	2.81	2.80	2.73	2.73	2.76	2.75
Al	1.21	1.20	1.15	1.15	1.12	1.26	1.27	1.28	1.27	1.28	1.28
K	0.01	0.00	0.00	0.00	0.01	0.12	0.06	0.04	0.00	0.10	0.09
Ca	0.21	0.19	0.14	0.15	0.11	0.05	0.04	0.26	0.27	0.11	0.18
Na	0.79	0.82	0.85	0.87	0.84	0.72	0.81	0.67	0.69	0.66	0.67
Fe	0.00	0.00	0.00	0.00	0.02	0.02	0.01	0.02	0.02	0.05	0.03
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Ab	78.9	80.9	85.4	84.9	87.4	81.3	89.2	69.7	71.5	75.3	72.0
% An	20.6	18.7	14.3	14.7	11.6	5.6	4.6	26.6	28.1	12.7	18.9
% Or	0.5	0.4	0.4	0.4	1.0	13.1	6.2	3.7	0.4	12.0	9.1

MT98-146 Plagioclase (Continued)

Sample	P208	P209	P210	P211	P212	P213	P214	P215	P216	P217	P218
SiO ₂	60.49	62.47	62.48	62.32	63.49	60.94	60.79	63.25	63.94	62.84	64.17
Al ₂ O ₃	23.24	23.04	23.15	23.21	22.22	23.40	24.23	22.43	21.71	22.68	21.76
K ₂ O	1.68	0.06	0.09	0.09	0.70	2.41	1.79	0.08	0.09	0.08	0.08
CaO	1.85	4.48	4.62	4.64	2.68	1.46	3.42	3.80	3.28	4.19	3.05
Na ₂ O	7.69	8.46	8.60	8.47	8.87	7.45	7.25	8.79	9.20	8.64	9.39
FeO	2.20	0.31	0.14	0.25	0.39	0.60	0.52	0.00	0.02	0.02	0.06
SrO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BaO	0.15	0.00	0.03	0.01	0.15	0.07	0.03	0.15	0.00	0.08	0.14
Total	97.30	98.82	99.11	98.99	98.49	96.34	98.04	98.50	98.24	98.53	98.64

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.77	2.79	2.79	2.78	2.85	2.80	2.75	2.83	2.86	2.81	2.86
Al	1.26	1.21	1.22	1.22	1.17	1.27	1.29	1.18	1.15	1.20	1.14
K	0.10	0.00	0.00	0.00	0.04	0.14	0.10	0.00	0.00	0.00	0.00
Ca	0.09	0.21	0.22	0.22	0.13	0.07	0.17	0.18	0.16	0.20	0.15
Na	0.68	0.73	0.74	0.73	0.77	0.66	0.64	0.76	0.80	0.75	0.81
Fe	0.08	0.01	0.01	0.01	0.01	0.02	0.02	0.00	0.00	0.00	0.00
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
%Ab	78.3	77.1	76.7	76.4	82.0	75.7	70.3	80.3	83.1	78.5	84.4
%An	10.4	22.6	22.8	23.1	13.7	8.2	18.3	19.2	16.4	21.0	15.1
%Or	11.3	0.3	0.5	0.5	4.3	16.1	11.4	0.5	0.5	0.5	0.5

MT98-146 Plagioclase (Continued)

Sample	P219	P220	P221	P222	P223	P224	P225	P226	P227	P228	P229
SiO ₂	63.62	62.83	62.76	63.02	63.30	63.13	61.66	65.09	62.06	64.58	65.18
Al ₂ O ₃	22.15	22.58	22.63	22.56	22.25	22.23	22.71	21.25	23.06	21.71	21.21
K ₂ O	0.05	0.07	0.09	0.09	0.10	0.08	0.11	0.13	0.11	0.08	0.04
CaO	3.54	4.05	4.53	3.95	3.78	3.94	4.42	2.32	4.63	2.50	2.19
Na ₂ O	9.10	8.78	8.52	8.90	8.90	8.90	8.35	9.61	8.52	9.82	9.83
FeO	0.12	0.12	0.09	0.05	0.01	0.00	0.07	0.08	0.00	0.03	0.07
SrO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BaO	0.00	0.00	0.16	0.36	0.22	0.01	0.00	0.00	0.01	0.00	0.04
Total	98.57	98.44	98.78	98.93	98.56	98.29	97.33	98.48	98.39	98.72	98.56

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.84	2.81	2.81	2.82	2.83	2.83	2.80	2.90	2.79	2.87	2.90
Al	1.17	1.19	1.19	1.19	1.17	1.17	1.21	1.11	1.22	1.14	1.11
K	0.00	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.00	0.00
Ca	0.17	0.19	0.22	0.19	0.18	0.19	0.21	0.11	0.22	0.12	0.10
Na	0.79	0.76	0.74	0.77	0.77	0.77	0.73	0.83	0.74	0.85	0.85
Fe	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
%Ab	82.1	79.3	76.9	79.9	80.5	80.0	76.9	87.5	76.4	87.2	88.8
%An	17.6	20.2	22.6	19.6	18.9	19.5	22.5	11.7	22.9	12.3	10.9
%Or	0.3	0.4	0.5	0.5	0.6	0.5	0.6	0.8	0.6	0.5	0.2

MT98-146 Plagioclase (Continued)

Sample	P230	P231	P232	P233	P234	P235	P236	P237	P238	P239	P240
SiO ₂	62.90	65.84	67.34	62.62	60.33	62.56	63.16	60.51	61.22	63.24	62.13
Al ₂ O ₃	22.50	20.72	19.70	22.88	24.43	22.95	23.01	24.46	24.09	23.24	23.14
K ₂ O	0.10	0.07	0.07	0.07	0.07	0.04	0.05	0.06	0.07	0.06	0.56
CaO	3.93	1.95	0.30	4.19	6.14	4.28	4.25	5.88	5.37	4.45	4.45
Na ₂ O	8.85	9.92	10.97	8.76	7.71	8.74	8.73	7.84	8.00	8.74	8.22
FeO	0.05	0.02	0.23	0.11	0.33	0.19	0.29	0.24	0.27	0.27	0.26
SrO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BaO	0.17	0.00	0.00	0.06	0.17	0.00	0.02	0.12	0.13	0.00	0.00
Total	98.49	98.54	98.60	98.70	99.18	98.77	99.52	99.11	99.15	99.99	98.75

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.82	2.92	2.98	2.80	2.71	2.80	2.80	2.71	2.74	2.79	2.78
Al	1.19	1.08	1.03	1.21	1.29	1.21	1.20	1.29	1.27	1.21	1.22
K	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Ca	0.19	0.09	0.01	0.20	0.30	0.20	0.20	0.28	0.26	0.21	0.21
Na	0.77	0.85	0.94	0.76	0.67	0.76	0.75	0.68	0.69	0.75	0.71
Fe	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Ab	79.8	89.8	98.1	78.7	69.1	78.5	78.5	70.4	72.6	77.8	74.4
% An	19.6	9.8	1.5	20.8	30.4	21.2	21.1	29.2	26.9	21.9	22.3
% Or	0.6	0.4	0.4	0.4	0.4	0.3	0.3	0.4	0.4	0.3	3.3

MT98-146 Plagioclase (Continued)

Sample	P241	P242	P243	P244	P245	P246	P247	P248	P249	P250	P251
SiO ₂	63.28	63.37	62.99	62.93	62.93	62.12	63.17	62.48	60.02	60.18	63.16
Al ₂ O ₃	22.66	22.97	22.60	22.96	23.02	23.08	23.47	24.15	24.91	25.06	23.21
K ₂ O	0.07	0.06	0.08	0.08	0.05	0.05	0.17	0.06	0.06	0.08	0.06
CaO	4.23	4.15	4.04	4.21	4.27	4.53	4.05	4.72	6.52	6.37	4.01
Na ₂ O	8.84	8.84	9.09	8.85	8.93	8.63	9.21	8.97	8.04	8.30	9.58
FeO	0.09	0.11	0.28	0.20	0.10	0.05	0.26	0.10	0.31	0.30	0.24
SrO	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.10	0.09	0.07	0.03
BaO	0.00	0.00	0.05	0.00	0.14	0.00	0.00	0.24	0.06	0.00	0.00
Total	99.16	99.49	99.13	99.23	99.44	98.46	100.39	100.82	100.00	100.36	100.28

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.82	2.81	2.81	2.80	2.80	2.79	2.79	2.75	2.68	2.68	2.79
Al	1.19	1.20	1.19	1.20	1.21	1.22	1.22	1.25	1.31	1.31	1.21
K	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Ca	0.20	0.20	0.19	0.20	0.20	0.22	0.19	0.22	0.31	0.30	0.19
Na	0.76	0.76	0.79	0.76	0.77	0.75	0.79	0.77	0.70	0.72	0.82
Fe	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.00	0.01	0.01	0.01
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Ab	78.8	79.1	79.9	78.8	78.9	77.3	79.7	77.2	68.8	69.9	80.9
% An	20.8	20.5	19.7	20.7	20.8	22.4	19.4	22.4	30.9	29.7	18.7
% Or	0.4	0.3	0.4	0.5	0.3	0.3	1.0	0.3	0.3	0.4	0.3

MT98-146 Plagioclase (Continued)

Sample	P252	P253	P254	P255	P256	P257	P258	P259	P260	P261	P262
SiO ₂	63.60	62.34	63.20	63.48	62.82	63.32	63.23	63.30	63.20	63.01	63.52
Al ₂ O ₃	23.14	24.17	23.38	23.19	23.05	23.13	23.22	23.30	23.23	23.06	23.62
K ₂ O	0.07	0.31	0.10	0.11	1.22	0.17	0.08	0.09	0.10	0.08	0.10
CaO	4.02	4.60	4.19	4.01	2.92	4.09	4.06	4.21	3.90	4.19	4.07
Na ₂ O	9.59	8.78	9.24	9.47	8.94	9.30	9.42	9.41	9.56	9.26	9.45
FeO	0.22	0.14	0.07	0.00	0.34	0.07	0.09	0.11	0.08	0.05	0.06
SrO	0.10	0.02	0.02	0.00	0.03	0.05	0.06	0.02	0.00	0.07	0.04
BaO	0.00	0.00	0.00	0.15	0.30	0.13	0.11	0.09	0.00	0.13	0.02
Total	100.75	100.36	100.20	100.41	99.60	100.25	100.26	100.52	100.06	99.86	100.88

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.80	2.75	2.79	2.80	2.80	2.80	2.79	2.79	2.79	2.79	2.79
Al	1.20	1.26	1.22	1.20	1.21	1.20	1.21	1.21	1.21	1.21	1.22
K	0.00	0.02	0.01	0.01	0.07	0.01	0.00	0.01	0.01	0.00	0.01
Ca	0.19	0.22	0.20	0.19	0.14	0.19	0.19	0.20	0.18	0.20	0.19
Na	0.82	0.75	0.79	0.81	0.77	0.80	0.81	0.80	0.82	0.80	0.80
Fe	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
%Ab	80.9	76.2	79.5	80.5	78.7	79.7	80.4	79.8	81.1	79.6	80.3
%An	18.7	22.1	19.9	18.9	14.2	19.4	19.1	19.7	18.3	19.9	19.1
%Or	0.4	1.8	0.5	0.6	7.0	0.9	0.4	0.5	0.6	0.5	0.5

MT98-146 Plagioclase (Continued)

Sample	P263	P264	P265	P266	P267	P268	P271	P272	P273	P274	P275
SiO ₂	63.19	62.39	63.92	63.93	62.57	62.05	62.82	65.07	62.93	63.70	63.24
Al ₂ O ₃	23.03	23.45	22.60	22.79	23.86	23.66	23.13	22.28	23.04	23.11	23.09
K ₂ O	0.08	0.06	0.22	0.06	0.07	0.08	0.41	0.09	0.07	0.08	0.09
CaO	4.09	4.81	3.68	3.66	4.79	4.59	4.04	3.19	4.19	3.68	4.28
Na ₂ O	9.62	9.18	9.50	9.72	9.11	9.05	9.41	10.17	9.35	9.80	9.36
FeO	0.10	0.01	0.05	0.06	0.07	0.07	0.15	0.04	0.00	0.02	0.01
SrO	0.01	0.02	0.03	0.03	0.05	0.02	0.00	0.00	0.09	0.00	0.02
BaO	0.00	0.00	0.00	0.11	0.06	0.00	0.00	0.11	0.00	0.04	0.02
Total	100.12	99.92	100.00	100.36	100.60	99.51	99.97	100.95	99.66	100.43	100.10

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.79	2.77	2.82	2.82	2.76	2.76	2.79	2.85	2.79	2.80	2.79
Al	1.20	1.23	1.18	1.18	1.24	1.24	1.21	1.15	1.21	1.20	1.20
K	0.00	0.00	0.01	0.00	0.00	0.00	0.02	0.01	0.00	0.00	0.00
Ca	0.19	0.23	0.17	0.17	0.23	0.22	0.19	0.15	0.20	0.17	0.20
Na	0.82	0.79	0.81	0.83	0.78	0.78	0.81	0.86	0.80	0.84	0.80
Fe	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
%Ab	80.6	77.3	81.3	82.5	77.2	77.8	79.0	84.8	79.9	82.5	79.4
%An	19.0	22.4	17.4	17.2	22.4	21.8	18.7	14.7	19.8	17.1	20.1
%Or	0.5	0.3	1.3	0.4	0.4	0.4	2.3	0.5	0.4	0.4	0.5

MT98-146 Plagioclase (Continued)

Sample	P276	P277	P278	P279	P280	P281	P282	P283	P284	P285	P286
SiO ₂	64.23	63.07	63.62	62.88	63.44	62.85	62.79	64.22	63.38	63.44	65.67
Al ₂ O ₃	23.01	23.43	23.37	23.14	23.20	23.66	23.53	23.22	23.49	23.66	22.16
K ₂ O	0.04	0.06	0.07	0.06	0.06	0.09	0.06	0.38	0.39	0.07	0.06
CaO	3.65	4.18	4.13	4.06	3.96	4.53	4.45	3.32	3.50	4.20	2.98
Na ₂ O	9.90	9.50	9.48	9.43	9.52	9.10	9.32	9.48	9.41	9.36	10.25
FeO	0.00	0.00	0.03	0.05	0.00	0.06	0.02	0.07	0.02	0.03	0.09
SrO	0.03	0.01	0.08	0.08	0.00	0.02	0.11	0.02	0.00	0.08	0.00
BaO	0.26	0.26	0.00	0.00	0.06	0.00	0.19	0.00	0.00	0.00	0.00
Total	101.13	100.52	100.77	99.70	100.24	100.32	100.47	100.71	100.19	100.84	101.20

Number of cations in formula based on n oxygens

n	8	8	8	8	8	8	8	8	8	8	8
Si	2.81	2.78	2.79	2.79	2.80	2.77	2.77	2.81	2.79	2.78	2.86
Al	1.19	1.22	1.21	1.21	1.21	1.23	1.23	1.20	1.22	1.22	1.14
K	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.02	0.02	0.00	0.00
Ca	0.17	0.20	0.19	0.19	0.19	0.21	0.21	0.16	0.17	0.20	0.14
Na	0.84	0.81	0.81	0.81	0.81	0.78	0.80	0.81	0.80	0.80	0.87
Fe	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
%Ab	82.9	80.1	80.3	80.5	81.0	78.0	78.9	82.0	81.1	79.8	85.9
%An	16.9	19.5	19.3	19.2	18.6	21.5	20.8	15.9	16.7	19.8	13.8
%Or	0.2	0.4	0.4	0.4	0.3	0.5	0.3	2.1	2.2	0.4	0.3

MT98-146 Plagioclase (Continued)

Sample	P287	P288	P289	P290	P291
SiO ₂	65.17	62.73	63.09	63.81	64.20
Al ₂ O ₃	22.19	24.16	23.99	23.36	23.01
K ₂ O	0.07	1.00	0.08	0.05	0.52
CaO	2.79	3.44	4.41	4.16	3.10
Na ₂ O	10.21	8.61	9.07	9.32	9.36
FeO	0.02	0.17	0.03	0.10	0.14
SrO	0.06	0.07	0.02	0.08	0.02
BaO	0.19	0.00	0.00	0.13	0.00
Total	100.70	100.18	100.68	101.01	100.36

Number of cations in formula based on n oxygens

n	8	8	8	8	8
Si	2.86	2.77	2.77	2.80	2.82
Al	1.15	1.26	1.24	1.21	1.19
K	0.00	0.06	0.00	0.00	0.03
Ca	0.13	0.16	0.21	0.20	0.15
Na	0.87	0.74	0.77	0.79	0.80
Fe	0.00	0.01	0.00	0.00	0.01
Sr	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.00	0.00	0.00
% Ab	86.6	77.1	78.5	80.0	82.0
% An	13.1	17.0	21.1	19.7	15.0
% Or	0.4	5.9	0.4	0.3	3.0

biotite

MT98-146 Biotite

Sample	B7	B8	B9	B10	B25	B26	B44	B45	B46	B62	B63	B127	B128	B131
SiO ₂	37.63	34.38	36.19	33.96	36.03	35.52	34.89	35.74	35.91	35.92	35.87	36.50	35.78	35.79
Al ₂ O ₃	21.77	20.17	20.84	19.92	20.23	20.77	19.84	19.80	19.06	19.09	19.17	19.57	19.73	19.08
TiO ₂	0.65	0.62	0.60	0.52	0.52	0.48	1.25	1.46	1.45	1.71	1.70	1.60	1.56	1.64
Cr ₂ O ₃	0.09	0.08	0.03	0.05	0.06	0.05	0.00	0.19	0.03	0.17	0.12	0.11	0.07	0.11
FeO	16.49	17.32	17.03	18.05	15.83	15.95	16.26	16.03	16.00	15.85	16.10	15.26	15.76	15.57
MnO	0.00	0.07	0.06	0.14	0.05	0.07	0.08	0.03	0.09	0.01	0.09	0.05	0.07	0.07
K ₂ O	8.66	9.11	8.76	7.04	8.40	8.52	8.06	9.18	8.65	9.00	8.70	8.59	8.97	8.99
MgO	11.47	11.12	12.28	11.34	12.50	12.27	11.52	11.64	11.62	12.04	11.84	12.14	11.71	12.49
CaO	0.08	0.08	0.04	0.13	0.04	0.12	0.03	0.05	0.02	0.01	0.04	0.04	0.05	0.01
Na ₂ O	0.27	0.18	0.13	0.06	0.06	0.14	0.11	0.09	0.03	0.06	0.06	0.04	0.00	0.14
Cl	0.05	0.01	0.05	0.00	0.04	0.03	0.09	0.08	0.05	0.04	0.04	0.06	0.03	0.03
BaO	0.08	0.21	0.25	0.17	0.04	0.34	0.59	0.17	0.00	0.34	0.42	0.15	0.13	0.21
Total	97.24	93.35	96.27	91.39	93.80	94.28	92.73	94.46	92.91	94.23	94.15	94.11	93.86	94.13

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Si	2.97	2.89	2.92	2.89	2.96	2.91	2.92	2.94	2.99	2.95	2.96	2.98	2.95	2.95
Al iv	1.03	1.11	1.08	1.11	1.04	1.09	1.08	1.06	1.01	1.05	1.04	1.02	1.05	1.05
Al vi	1.00	0.89	0.90	0.89	0.92	0.92	0.88	0.86	0.86	0.81	0.82	0.87	0.86	0.80
Ti	0.04	0.04	0.04	0.03	0.03	0.03	0.08	0.09	0.09	0.11	0.11	0.10	0.10	0.10
Cr	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.00	0.01
Fe	1.09	1.22	1.15	1.28	1.09	1.09	1.14	1.10	1.11	1.09	1.11	1.04	1.09	1.07
Mn	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00
K	0.87	0.98	0.90	0.76	0.88	0.89	0.86	0.96	0.92	0.94	0.92	0.90	0.94	0.94
Mg	1.35	1.39	1.48	1.44	1.53	1.50	1.44	1.43	1.44	1.48	1.46	1.48	1.44	1.53
Ca	0.01	0.01	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Na	0.04	0.03	0.02	0.01	0.01	0.02	0.02	0.01	0.00	0.01	0.01	0.01	0.00	0.02
Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.01	0.01	0.01	0.00	0.01	0.02	0.01	0.00	0.01	0.01	0.00	0.00	0.01
Fe/Fe+Mg	0.45	0.47	0.44	0.47	0.42	0.42	0.44	0.44	0.44	0.42	0.43	0.41	0.43	0.41

biotite

MT98-146 Biotite (Continued)

Sample	B132	B137	B138	B141	B142	B143	B144	B168	B169	B170	B171	B174	B175	B193
SiO ₂	35.72	36.30	35.37	35.90	34.62	35.12	36.36	35.72	35.57	34.66	34.03	36.24	35.30	35.20
Al ₂ O ₃	19.44	19.41	19.22	20.20	19.77	19.87	21.76	19.94	19.64	19.50	19.73	19.68	19.13	19.15
TiO ₂	1.48	1.57	1.64	1.19	1.10	1.46	1.36	1.25	1.23	1.41	1.20	1.71	1.70	1.74
Cr ₂ O ₃	0.06	0.18	0.11	0.10	0.14	0.18	0.15	0.09	0.14	0.04	0.12	0.07	0.09	0.04
FeO	15.80	14.89	15.28	14.56	15.66	15.17	13.41	15.49	16.07	16.14	17.46	15.65	15.74	15.91
MnO	0.04	0.00	0.05	0.05	0.09	0.06	0.00	0.06	0.10	0.02	0.00	0.06	0.08	0.06
K ₂ O	8.69	8.91	9.14	8.87	8.62	8.84	8.45	9.26	9.29	9.34	8.43	9.15	8.96	8.71
MgO	12.33	12.34	11.92	12.01	11.67	11.60	9.80	11.82	11.60	11.30	11.09	11.98	11.73	12.15
CaO	0.00	0.00	0.00	0.01	0.02	0.02	0.05	0.04	0.04	0.05	0.06	0.01	0.00	0.06
Na ₂ O	0.07	0.16	0.14	0.16	0.12	0.19	0.17	0.11	0.06	0.02	0.00	0.12	0.11	0.08
Cl	0.05	0.02	0.05	0.02	0.01	0.03	0.00	0.01	0.04	0.04	0.05	0.00	0.04	0.06
BaO	0.40	0.19	0.42	0.17	0.21	0.13	0.40	0.45	0.00	0.28	0.36	0.30	0.17	0.40
Total	94.07	93.98	93.35	93.23	92.03	92.66	91.91	94.24	93.78	92.82	92.53	94.96	93.06	93.56

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Si	2.94	2.97	2.94	2.96	2.92	2.93	3.01	2.94	2.95	2.92	2.88	2.95	2.94	2.92
Al iv	1.06	1.03	1.06	1.04	1.08	1.07	0.99	1.06	1.05	1.08	1.12	1.05	1.06	1.08
Al vi	0.83	0.85	0.82	0.93	0.88	0.88	1.13	0.88	0.86	0.85	0.85	0.84	0.82	0.80
Ti	0.09	0.10	0.10	0.07	0.07	0.09	0.08	0.08	0.08	0.09	0.08	0.10	0.11	0.11
Cr	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.01	0.00
Fe	1.09	1.02	1.06	1.00	1.10	1.06	0.93	1.07	1.11	1.14	1.24	1.07	1.10	1.11
Mn	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00
K	0.91	0.93	0.97	0.93	0.93	0.94	0.89	0.97	0.98	1.00	0.91	0.95	0.95	0.92
Mg	1.51	1.51	1.48	1.48	1.47	1.44	1.21	1.45	1.43	1.42	1.40	1.46	1.46	1.51
Ca	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01
Na	0.01	0.03	0.02	0.02	0.02	0.03	0.03	0.02	0.01	0.00	0.00	0.02	0.02	0.01
Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01
Fe/Fe+Mg	0.42	0.40	0.42	0.40	0.43	0.42	0.43	0.42	0.44	0.44	0.47	0.42	0.43	0.42

biotite

MT98-146 Biotite (Continued)

Sample	B194	B195	B196	B199	B200	B201	B202	B207	B210	B214	B215	B216	B217	B218
SiO ₂	36.15	35.26	37.60	33.98	32.33	32.43	30.46	35.99	33.51	35.58	35.26	35.40	34.98	34.41
Al ₂ O ₃	18.62	18.73	19.54	19.90	19.77	19.82	19.51	19.55	19.62	19.07	19.28	18.98	19.36	19.01
TiO ₂	1.73	1.50	1.49	1.17	1.13	1.08	0.82	1.50	1.30	1.60	1.58	1.64	1.64	1.66
Cr ₂ O ₃	0.12	0.06	0.04	0.10	0.00	0.09	0.00	0.00	0.00	0.13	0.11	0.00	0.05	0.16
FeO	15.53	15.52	14.67	18.03	19.39	20.97	24.68	16.27	18.02	16.13	15.59	15.22	15.60	16.86
MnO	0.06	0.08	0.02	0.10	0.03	0.08	0.06	0.00	0.00	0.06	0.02	0.00	0.05	0.04
K ₂ O	8.84	8.59	9.04	7.91	6.82	5.88	3.98	8.94	8.15	9.03	8.86	9.06	8.34	8.34
MgO	12.47	12.52	12.88	11.16	10.90	10.88	10.59	10.86	11.43	12.27	12.16	12.39	11.65	11.99
CaO	0.01	0.07	0.08	0.07	0.01	0.03	0.03	0.16	0.01	0.01	0.04	0.00	0.04	0.02
Na ₂ O	0.08	0.08	0.10	0.14	0.05	0.07	0.00	0.18	0.11	0.12	0.08	0.10	0.06	0.10
Cl	0.03	0.00	0.04	0.03	0.00	0.01	0.02	0.05	0.03	0.08	0.03	0.03	0.03	0.04
BaO	0.04	0.00	0.47	0.26	0.44	0.00	0.00	0.74	0.04	0.37	0.37	0.08	0.00	0.16
Total	93.68	92.41	95.96	92.84	90.87	91.32	90.15	94.25	92.21	94.45	93.37	92.90	91.80	92.78

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Si	2.98	2.95	3.01	2.87	2.80	2.79	2.69	2.97	2.85	2.93	2.93	2.95	2.94	2.89
Al iv	1.02	1.05	0.99	1.13	1.20	1.21	1.31	1.03	1.15	1.07	1.07	1.05	1.06	1.11
Al vi	0.79	0.79	0.86	0.85	0.82	0.80	0.73	0.88	0.81	0.79	0.82	0.81	0.85	0.78
Ti	0.11	0.09	0.09	0.07	0.07	0.07	0.05	0.09	0.08	0.10	0.10	0.10	0.10	0.10
Cr	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.01
Fe	1.07	1.08	0.98	1.27	1.41	1.51	1.82	1.12	1.28	1.11	1.08	1.06	1.10	1.19
Mn	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.93	0.92	0.92	0.85	0.75	0.65	0.45	0.94	0.88	0.95	0.94	0.96	0.89	0.89
Mg	1.53	1.56	1.54	1.40	1.41	1.40	1.40	1.34	1.45	1.51	1.51	1.54	1.46	1.50
Ca	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Na	0.01	0.01	0.02	0.02	0.01	0.01	0.00	0.03	0.02	0.02	0.01	0.02	0.01	0.02
Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.00	0.01	0.01	0.02	0.00	0.00	0.02	0.00	0.01	0.01	0.00	0.00	0.01
Fe/Fe+Mg	0.41	0.41	0.39	0.48	0.50	0.52	0.57	0.46	0.47	0.42	0.42	0.41	0.43	0.44

biotite

MT98-146 Biotite (Continued)

Sample	B219	B221	B222	B223	B224	B225	B230	B231	B233	B240	B241
SiO ₂	34.96	34.85	35.50	35.39	34.85	34.55	35.01	35.65	34.91	34.65	34.20
Al ₂ O ₃	19.26	18.87	18.95	18.91	19.36	19.31	19.26	18.95	19.34	19.45	19.60
TiO ₂	1.74	1.64	1.70	1.69	1.36	1.42	1.61	1.53	1.52	1.58	1.48
Cr ₂ O ₃	0.15	0.15	0.21	0.05	0.09	0.06	0.13	0.21	0.00	0.11	0.12
FeO	15.63	15.52	15.74	15.72	15.78	15.50	15.15	15.43	15.51	16.29	16.74
MnO	0.07	0.08	0.01	0.03	0.02	0.01	0.06	0.03	0.00	0.07	0.03
K ₂ O	8.89	8.12	8.88	8.83	8.92	8.83	8.88	8.97	8.72	9.20	9.24
MgO	12.10	12.59	12.27	12.17	12.04	11.86	12.14	12.12	12.13	11.38	11.27
CaO	0.01	0.07	0.00	0.11	0.01	0.03	0.00	0.02	0.08	0.02	0.00
Na ₂ O	0.13	0.10	0.10	0.11	0.08	0.10	0.07	0.11	0.14	0.05	0.01
Cl	0.04	0.04	0.02	0.03	0.01	0.02	0.01	0.02	0.03	0.05	0.02
BaO	0.27	0.33	0.43	0.39	0.43	0.39	0.43	0.04	0.08	0.27	0.20
Total	93.24	92.34	93.81	93.43	92.94	92.07	92.73	93.09	92.46	93.09	92.92

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	2.91	2.92	2.94	2.94	2.92	2.92	2.93	2.97	2.92	2.91	2.88
Al iv	1.09	1.08	1.06	1.06	1.08	1.08	1.07	1.03	1.08	1.09	1.12
Al vi	0.81	0.78	0.79	0.79	0.83	0.84	0.83	0.82	0.83	0.83	0.83
Ti	0.11	0.10	0.11	0.11	0.09	0.09	0.10	0.10	0.10	0.10	0.09
Cr	0.01	0.01	0.01	0.00	0.01	0.00	0.01	0.01	0.00	0.01	0.01
Fe	1.09	1.09	1.09	1.09	1.11	1.09	1.06	1.07	1.09	1.14	1.18
Mn	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.95	0.87	0.94	0.94	0.95	0.95	0.95	0.95	0.93	0.98	0.99
Mg	1.50	1.57	1.51	1.51	1.50	1.49	1.51	1.50	1.51	1.42	1.42
Ca	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Na	0.02	0.02	0.02	0.02	0.01	0.02	0.01	0.02	0.02	0.01	0.00
Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.01
Fe/Fe+Mg	0.42	0.41	0.42	0.42	0.42	0.42	0.41	0.42	0.42	0.45	0.45

MT98-146 Muscovite

Sample	M27	M28	M29	M92	M93	M123	M124	M125	M126	M139	M140	M153	M154	M191
SiO ₂	44.85	44.27	44.30	45.24	45.45	49.18	47.41	44.52	46.28	44.73	44.58	45.21	45.58	45.32
Al ₂ O ₃	36.91	36.71	36.77	34.57	35.11	32.45	31.43	29.86	31.31	30.83	30.62	30.89	30.81	35.38
TiO ₂	0.02	0.04	0.06	0.59	0.62	0.04	0.01	0.07	0.06	0.02	0.03	0.01	0.01	0.69
Cr ₂ O ₃	0.05	0.01	0.02	0.01	0.11	0.00	0.00	0.00	0.00	0.04	0.00	0.06	0.04	0.03
FeO	1.26	1.04	1.21	1.04	1.10	2.57	2.23	3.23	3.33	4.12	3.92	3.75	3.73	0.85
MnO	0.06	0.09	0.07	0.00	0.00	0.02	0.01	0.03	0.02	0.00	0.01	0.07	0.00	0.00
K ₂ O	8.71	8.49	8.35	8.94	8.82	8.10	8.01	8.14	8.69	9.29	9.11	9.86	9.77	9.02
MgO	0.54	0.47	0.49	1.09	1.06	1.90	1.80	2.43	2.36	3.08	2.73	3.27	3.09	0.78
CaO	0.02	0.06	0.09	0.06	0.05	0.09	0.10	0.09	0.03	0.04	0.08	0.09	0.08	0.03
Na ₂ O	0.99	0.97	1.09	0.77	0.87	0.03	0.11	0.08	0.14	0.10	0.17	0.02	0.04	0.83
Cl	0.03	0.03	0.02	0.00	0.00	0.00	0.02	0.00	0.02	0.03	0.01	0.00	0.00	0.01
BaO	1.24	0.96	1.28	0.48	0.38	0.70	0.84	0.00	0.59	0.26	0.35	0.00	0.07	0.26
Total	94.88	93.32	93.92	93.00	93.70	95.20	92.04	88.52	92.95	92.66	91.85	93.36	93.50	93.39

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Si	3.28	3.27	3.27	3.35	3.34	3.54	3.54	3.47	3.46	3.38	3.40	3.39	3.42	3.33
Al iv	0.72	0.73	0.73	0.65	0.66	0.46	0.46	0.53	0.54	0.62	0.60	0.61	0.58	0.67
Al vi	2.45	2.47	2.46	2.37	2.37	2.29	2.30	2.21	2.22	2.13	2.16	2.12	2.14	2.40
Ti	0.00	0.00	0.00	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04
Cr	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe	0.08	0.06	0.07	0.06	0.07	0.15	0.14	0.21	0.21	0.26	0.25	0.24	0.23	0.05
Mn	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.81	0.80	0.78	0.84	0.83	0.74	0.76	0.81	0.83	0.90	0.89	0.94	0.93	0.85
Mg	0.06	0.05	0.05	0.12	0.12	0.20	0.20	0.28	0.26	0.35	0.31	0.37	0.34	0.09
Ca	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.00
Na	0.14	0.14	0.16	0.11	0.12	0.00	0.02	0.01	0.02	0.01	0.02	0.00	0.01	0.12
Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.04	0.03	0.04	0.01	0.01	0.02	0.02	0.00	0.02	0.01	0.01	0.00	0.00	0.01

MT98-146 Muscovite

Sample	M192	M197	M198
SiO ₂	47.47	45.25	45.12
Al ₂ O ₃	32.82	35.35	35.33
TiO ₂	0.70	0.52	0.44
Cr ₂ O ₃	0.00	0.03	0.10
FeO	1.11	0.88	0.73
MnO	0.04	0.00	0.00
K ₂ O	8.83	9.88	9.19
MgO	1.60	0.80	0.80
CaO	0.01	0.00	0.04
Na ₂ O	0.70	0.75	1.02
Cl	0.01	0.01	0.00
BaO	0.29	0.35	0.31
Total	93.75	94.17	93.20

Number of cations in formula based on n oxygens

n	12	12	12
Si	3.47	3.33	3.33
Al iv	0.53	0.67	0.67
Al vi	2.30	2.39	2.40
Ti	0.04	0.03	0.02
Cr	0.00	0.00	0.01
Fe	0.07	0.05	0.04
Mn	0.00	0.00	0.00
K	0.82	0.93	0.87
Mg	0.17	0.09	0.09
Ca	0.00	0.00	0.00
Na	0.10	0.11	0.15
Cl	0.00	0.00	0.00
Ba	0.01	0.01	0.01

MT98-146 Garnet

Sample	G1	G2	G3	G14	G16	G21	G22	G23	G32	G31	G30
SiO ₂	36.37	36.63	36.32	36.32	36.28	36.53	36.49	36.83	37.38	33.76	36.32
Al ₂ O ₃	20.97	20.92	20.82	20.92	20.79	20.82	21.09	21.22	21.22	16.17	20.90
TiO ₂	0.12	0.12	0.11	0.11	0.06	0.08	0.11	0.07	0.08	0.06	0.06
Cr ₂ O ₃	0.00	0.09	0.04	0.06	0.01	0.00	0.06	0.07	0.06	0.03	0.06
FeO	31.95	31.68	31.17	31.03	33.97	33.17	30.99	30.54	30.75	31.01	32.18
MnO	1.25	1.21	1.77	2.20	2.97	2.67	1.48	2.15	2.69	0.51	2.05
MgO	2.44	2.45	2.06	2.09	2.16	2.11	2.76	2.57	2.42	2.76	2.90
CaO	6.17	6.06	6.20	6.07	2.58	4.03	6.07	5.95	5.31	4.88	4.15
Na ₂ O	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.01	0.00
K ₂ O	0.01	0.02	0.01	0.02	0.03	0.03	0.00	0.00	0.03	0.03	0.04
Total	99.30	99.17	98.50	98.82	98.85	99.44	99.05	99.40	100.02	89.21	98.67

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	2.95	2.97	2.97	2.96	2.97	2.97	2.95	2.97	2.99	3.07	2.96
Al iv	0.05	0.03	0.03	0.04	0.03	0.03	0.05	0.03	0.01	-0.07	0.04
Al vi	1.95	1.96	1.97	1.97	1.98	1.97	1.96	1.98	2.00	1.80	1.97
Ti	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.00
Cr	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe	2.17	2.14	2.13	2.11	2.33	2.26	2.10	2.06	2.06	2.36	2.19
Mn	0.09	0.08	0.12	0.15	0.21	0.18	0.10	0.15	0.18	0.04	0.14
Mg	0.30	0.30	0.25	0.25	0.26	0.26	0.33	0.31	0.29	0.37	0.35
Ca	0.54	0.53	0.54	0.53	0.23	0.35	0.53	0.51	0.46	0.48	0.36
Na	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Alm	70.3	70.4	69.9	69.3	77.0	74.0	68.6	68.0	69.0	72.6	71.9
% Sp	2.9	2.8	4.2	5.2	7.3	6.4	3.4	5.1	6.5	1.2	4.9
% Py	10.6	10.7	9.0	9.1	9.6	9.2	12.2	11.3	10.7	13.0	13.1
% Gr	21.0	20.8	21.7	21.0	8.1	13.0	20.8	20.4	18.0	17.2	13.5

MT98-146 Garnet (continued)

Sample	G48	G49	G50	G51	G52	G53	G54	G55	G56	G57	G58
SiO ₂	36.08	36.92	36.56	36.84	36.91	36.97	36.88	36.98	37.20	36.61	36.86
Al ₂ O ₃	20.77	21.30	21.20	21.26	21.34	21.27	21.17	21.33	21.24	21.18	21.22
TiO ₂	0.06	0.09	0.03	0.04	0.04	0.10	0.11	0.06	0.13	0.12	0.05
Cr ₂ O ₃	0.02	0.00	0.00	0.04	0.06	0.01	0.00	0.02	0.06	0.07	0.03
FeO	32.21	31.95	31.35	30.80	30.86	31.22	31.06	32.02	30.91	31.02	31.19
MnO	2.96	0.78	0.56	0.45	0.42	0.35	0.49	0.67	0.88	0.81	1.02
MgO	2.20	3.49	3.69	4.13	4.21	3.94	3.41	3.15	2.95	2.92	2.89
CaO	3.95	5.27	5.50	5.63	5.27	5.96	6.53	5.26	7.05	6.85	6.26
Na ₂ O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02
K ₂ O	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.01
Total	98.32	99.79	98.89	99.20	99.10	99.82	99.66	99.51	100.45	99.61	99.56

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	2.97	2.96	2.95	2.95	2.96	2.95	2.95	2.97	2.96	2.94	2.96
Al iv	0.03	0.04	0.05	0.05	0.04	0.05	0.05	0.03	0.04	0.06	0.04
Al vi	1.98	1.97	1.97	1.96	1.97	1.95	1.95	1.99	1.95	1.95	1.97
Ti	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.01	0.00
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe	2.21	2.14	2.11	2.06	2.07	2.08	2.08	2.15	2.06	2.09	2.10
Mn	0.21	0.05	0.04	0.03	0.03	0.02	0.03	0.05	0.06	0.06	0.07
Mg	0.27	0.42	0.44	0.49	0.50	0.47	0.41	0.38	0.35	0.35	0.35
Ca	0.35	0.45	0.48	0.48	0.45	0.51	0.56	0.45	0.60	0.59	0.54
Na	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Alm	72.9	69.9	68.8	67.2	67.8	67.5	67.5	71.1	67.1	67.7	68.7
% Sp	7.3	1.8	1.3	1.0	0.9	0.8	1.1	1.5	2.0	1.8	2.3
% Py	9.8	15.8	16.9	19.1	19.7	17.9	15.2	14.2	12.9	12.8	12.8
% Gr	12.9	17.3	18.3	18.7	17.4	19.8	22.2	17.6	24.4	23.7	21.5

MT98-146 Garnet (continued)

Sample	G59	G60	G41	G42	G88	G87	G86	G43	G70	G71	G72
SiO ₂	36.94	36.71	36.86	36.85	37.14	37.22	36.64	36.66	36.61	36.61	36.80
Al ₂ O ₃	21.06	21.12	21.14	21.10	21.20	21.40	21.23	21.03	20.83	21.04	20.94
TiO ₂	0.12	0.17	0.13	0.05	0.03	0.05	0.16	0.11	0.08	0.11	0.12
Cr ₂ O ₃	0.06	0.04	0.00	0.08	0.00	0.03	0.05	0.00	0.02	0.04	0.07
FeO	31.22	31.56	30.58	30.75	31.24	31.89	31.31	30.58	30.39	30.03	29.05
MnO	0.95	0.38	0.40	0.47	0.39	0.52	0.39	1.15	2.26	2.65	3.01
MgO	3.26	3.27	3.45	4.21	3.95	4.15	3.47	3.02	3.02	2.86	2.63
CaO	5.93	6.16	6.75	5.56	5.83	5.04	5.92	6.39	5.43	6.07	6.45
Na ₂ O	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.06	0.00
K ₂ O	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.01	0.00	0.00
Total	99.53	99.40	99.32	99.07	99.80	100.32	99.18	98.94	98.66	99.47	99.08

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	2.97	2.95	2.96	2.96	2.96	2.96	2.95	2.96	2.97	2.95	2.97
Al iv	0.03	0.05	0.04	0.04	0.04	0.04	0.05	0.04	0.03	0.05	0.03
Al vi	1.96	1.95	1.96	1.95	1.96	1.96	1.96	1.96	1.96	1.95	1.97
Ti	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe	2.10	2.12	2.05	2.06	2.08	2.12	2.11	2.07	2.06	2.02	1.96
Mn	0.06	0.03	0.03	0.03	0.03	0.04	0.03	0.08	0.16	0.18	0.21
Mg	0.39	0.39	0.41	0.50	0.47	0.49	0.42	0.36	0.37	0.34	0.32
Ca	0.51	0.53	0.58	0.48	0.50	0.43	0.51	0.55	0.47	0.52	0.56
Na	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Alm	68.5	69.1	66.8	67.1	67.7	68.9	68.8	67.5	67.5	65.9	64.5
% Sp	2.1	0.9	0.9	1.1	0.9	1.2	0.9	2.6	5.4	6.3	7.3
% Py	14.6	14.6	15.5	19.6	18.0	19.0	15.7	13.5	13.6	12.6	11.6
% Gr	20.0	20.9	23.3	18.4	19.3	16.2	20.0	22.1	18.3	20.6	22.5

MT98-146 Garnet (continued)

Sample	G73	G74	G75	G76	G77	G78	G79	G80	G81	G82	G83
SiO ₂	36.95	36.39	36.75	36.48	36.71	37.18	37.09	36.85	37.50	37.14	37.15
Al ₂ O ₃	20.99	20.72	21.23	20.91	21.31	21.29	21.17	21.00	21.42	21.38	21.57
TiO ₂	0.12	0.12	0.05	0.16	0.12	0.19	0.09	0.11	0.06	0.05	0.04
Cr ₂ O ₃	0.01	0.00	0.03	0.06	0.10	0.08	0.00	0.09	0.09	0.00	0.02
FeO	29.13	29.21	30.82	29.80	30.84	31.30	31.58	30.93	30.73	30.38	31.00
MnO	2.80	2.56	2.38	2.56	2.05	1.51	0.74	0.42	0.41	0.40	0.49
MgO	2.67	2.68	3.06	2.91	2.95	2.86	3.08	3.26	3.89	3.97	3.93
CaO	6.40	6.15	5.86	5.87	5.64	5.75	6.21	6.50	6.07	5.90	6.01
Na ₂ O	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00
K ₂ O	0.00	0.01	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.02
Total	99.08	97.85	100.17	98.76	99.71	100.15	99.96	99.15	100.18	99.25	100.23

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	2.98	2.97	2.94	2.96	2.95	2.97	2.97	2.97	2.97	2.97	2.95
Al iv	0.02	0.03	0.06	0.04	0.05	0.03	0.03	0.03	0.03	0.03	0.05
Al vi	1.98	1.97	1.95	1.96	1.97	1.97	1.96	1.96	1.97	1.98	1.97
Ti	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00
Cr	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.00	0.00
Fe	1.96	2.00	2.06	2.02	2.07	2.09	2.11	2.08	2.04	2.03	2.06
Mn	0.19	0.18	0.16	0.18	0.14	0.10	0.05	0.03	0.03	0.03	0.03
Mg	0.32	0.33	0.37	0.35	0.35	0.34	0.37	0.39	0.46	0.47	0.46
Ca	0.55	0.54	0.50	0.51	0.49	0.49	0.53	0.56	0.52	0.51	0.51
Na	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Alm	64.8	65.7	66.7	66.1	67.9	69.1	69.0	68.0	67.0	66.9	67.1
% Sp	6.7	6.2	5.5	6.1	4.8	3.5	1.7	0.9	0.9	0.9	1.1
% Py	11.8	12.1	13.4	13.0	13.1	12.7	13.6	14.6	17.8	18.4	17.9
% Gr	22.3	21.6	19.4	20.0	18.9	19.4	21.0	22.4	20.4	20.0	20.0

MT98-146 Garnet (continued)

Sample	G84	G85	G99	G100	G101	G102	G103	G104	G105	G106	G107
SiO ₂	37.03	36.71	36.72	36.28	36.29	37.27	36.68	37.03	37.05	36.97	36.92
Al ₂ O ₃	21.05	21.02	20.85	21.11	21.11	21.56	21.17	21.20	21.16	21.51	21.27
TiO ₂	0.02	0.04	0.03	0.05	0.02	0.05	0.12	0.15	0.09	0.04	0.13
Cr ₂ O ₃	0.07	0.01	0.01	0.02	0.06	0.04	0.02	0.03	0.03	0.04	0.01
FeO	31.18	32.09	32.41	32.69	33.19	30.68	31.19	31.87	30.89	31.78	31.04
MnO	0.71	0.93	1.33	2.02	1.54	0.47	0.47	0.48	0.37	0.46	0.27
MgO	4.12	3.81	3.55	3.45	3.59	4.22	3.14	4.48	5.13	4.89	3.16
CaO	5.05	4.28	4.28	3.39	3.41	5.87	6.44	4.23	4.13	4.23	6.70
Na ₂ O	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
K ₂ O	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.03	0.00	0.01	0.00
Total	99.24	98.89	99.18	99.01	99.22	100.18	99.26	99.50	98.85	99.94	99.54

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	2.97	2.97	2.97	2.95	2.94	2.95	2.95	2.96	2.97	2.94	2.96
Al iv	0.03	0.03	0.03	0.05	0.06	0.05	0.05	0.04	0.03	0.06	0.04
Al vi	1.96	1.97	1.95	1.97	1.96	1.97	1.96	1.96	1.96	1.96	1.97
Ti	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.01
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe	2.09	2.17	2.19	2.22	2.25	2.03	2.10	2.13	2.07	2.11	2.08
Mn	0.05	0.06	0.09	0.14	0.11	0.03	0.03	0.03	0.03	0.03	0.02
Mg	0.49	0.46	0.43	0.42	0.43	0.50	0.38	0.53	0.61	0.58	0.38
Ca	0.43	0.37	0.37	0.29	0.30	0.50	0.56	0.36	0.35	0.36	0.58
Na	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Alm	68.2	70.8	71.1	72.3	72.9	66.4	68.5	69.6	67.6	68.5	68.2
% Sp	1.6	2.1	3.0	4.7	3.6	1.0	1.1	1.1	0.8	1.0	0.6
% Py	19.1	17.6	16.1	15.7	16.4	19.4	14.0	21.1	25.0	23.1	14.1
% Gr	16.5	13.8	13.7	10.6	10.6	19.5	22.1	13.4	13.1	13.2	23.2

MT98-146 Garnet (continued)

Sample	G108	G109	G110	G111	G112	G113	G114	G115	G116	G117	G118
SiO ₂	37.69	36.92	36.33	36.47	36.74	36.74	36.71	36.68	36.80	36.87	37.12
Al ₂ O ₃	21.51	21.18	20.94	20.88	20.86	20.96	20.89	20.92	21.01	20.97	21.15
TiO ₂	0.12	0.10	0.11	0.16	0.13	0.14	0.11	0.12	0.13	0.14	0.20
Cr ₂ O ₃	0.06	0.02	0.00	0.02	0.05	0.05	0.09	0.04	0.03	0.02	0.06
FeO	31.32	31.41	30.73	29.51	29.17	29.64	29.68	29.29	29.19	30.03	30.72
MnO	0.35	0.67	2.47	3.01	3.51	3.48	3.63	3.49	3.47	3.28	2.72
MgO	3.13	2.92	2.67	2.17	2.10	1.90	1.86	1.86	1.93	2.09	2.21
CaO	6.42	6.43	5.65	7.00	6.83	6.73	6.54	6.76	6.87	6.41	6.17
Na ₂ O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00
K ₂ O	0.01	0.02	0.00	0.01	0.00	0.01	0.00	0.00	0.01	0.02	0.00
Total	100.60	99.67	98.89	99.22	99.40	99.66	99.52	99.16	99.41	99.85	100.36

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	2.98	2.96	2.95	2.96	2.97	2.97	2.97	2.97	2.97	2.97	2.97
Al iv	0.02	0.04	0.05	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Al vi	1.99	1.97	1.96	1.95	1.96	1.96	1.96	1.97	1.97	1.96	1.97
Ti	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Fe	2.07	2.11	2.09	2.00	1.97	2.00	2.01	1.99	1.97	2.02	2.06
Mn	0.02	0.05	0.17	0.21	0.24	0.24	0.25	0.24	0.24	0.22	0.18
Mg	0.37	0.35	0.32	0.26	0.25	0.23	0.22	0.22	0.23	0.25	0.26
Ca	0.54	0.55	0.49	0.61	0.59	0.58	0.57	0.59	0.59	0.55	0.53
Na	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Alm	68.9	69.0	68.0	65.0	64.5	65.6	65.9	65.4	65.0	66.3	67.8
% Sp	0.8	1.5	5.8	7.2	8.5	8.5	8.9	8.6	8.5	7.9	6.5
% Py	14.0	12.9	11.7	9.3	9.0	8.1	8.0	8.0	8.3	9.0	9.5
% Gr	22.1	22.1	19.1	24.6	24.0	23.6	22.9	24.0	24.4	22.1	21.1

MT98-146 Garnet (continued)

Sample	G119	G120	G121	G145	G146	G149	G150	G155	G156	G157	G160
SiO ₂	36.86	36.92	36.71	36.93	37.36	37.15	37.27	37.35	37.11	37.33	36.75
Al ₂ O ₃	20.72	21.02	21.12	21.33	21.34	21.43	21.36	21.56	21.36	21.40	21.08
TiO ₂	0.12	0.10	0.10	0.09	0.12	0.13	0.08	0.10	0.04	0.05	0.06
Cr ₂ O ₃	0.02	0.07	0.00	0.05	0.05	0.06	0.03	0.06	0.07	0.12	0.07
FeO	31.45	30.82	29.55	30.88	30.37	31.24	30.44	30.62	31.16	31.51	31.34
MnO	2.34	1.90	1.64	0.34	0.38	0.87	1.26	0.49	0.44	2.15	0.45
MgO	2.44	2.93	3.63	3.34	3.31	3.05	3.01	4.21	4.26	3.09	3.27
CaO	5.60	5.51	5.72	6.39	6.47	6.40	6.50	5.65	5.03	4.67	6.36
Na ₂ O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00
K ₂ O	0.00	0.00	0.01	0.02	0.01	0.02	0.00	0.00	0.01	0.00	0.01
Total	99.54	99.27	98.49	99.36	99.40	100.35	99.94	100.06	99.47	100.31	99.39

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	2.98	2.98	2.97	2.96	2.98	2.96	2.97	2.96	2.96	2.98	2.96
Al iv	0.02	0.02	0.03	0.04	0.02	0.04	0.03	0.04	0.04	0.02	0.04
Al vi	1.95	1.97	1.98	1.98	1.99	1.97	1.98	1.97	1.97	1.99	1.95
Ti	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.00
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Fe	2.13	2.08	2.00	2.07	2.03	2.08	2.03	2.03	2.08	2.10	2.11
Mn	0.16	0.13	0.11	0.02	0.03	0.06	0.09	0.03	0.03	0.15	0.03
Mg	0.29	0.35	0.44	0.40	0.39	0.36	0.36	0.50	0.51	0.37	0.39
Ca	0.48	0.48	0.50	0.55	0.55	0.55	0.56	0.48	0.43	0.40	0.55
Na	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Al ^{III}	69.4	68.5	65.7	68.1	67.6	68.3	67.0	66.8	68.3	69.8	68.5
% Sp	5.5	4.5	3.8	0.8	0.9	2.0	2.9	1.1	1.0	5.1	1.0
% Py	10.6	13.1	16.8	15.1	15.1	13.5	13.4	19.6	20.0	13.9	14.6
% Gr	18.8	18.6	19.5	22.0	22.6	21.8	22.5	18.7	16.4	15.3	21.6

MT98-146 Garnet (continued)

Sample	G161	G162	G163	G172	G173	G174	G175	G176	G177	G178	G179
SiO ₂	36.69	36.87	37.24	36.71	36.73	38.53	36.71	36.69	36.54	36.83	36.68
Al ₂ O ₃	21.33	21.31	21.37	21.10	21.28	22.38	21.18	21.19	21.16	20.96	21.08
TiO ₂	0.07	0.07	0.06	0.05	0.04	0.05	0.05	0.13	0.11	0.10	0.07
Cr ₂ O ₃	0.04	0.02	0.06	0.06	0.04	0.05	0.03	0.02	0.09	0.09	0.05
FeO	31.26	31.12	30.79	31.54	31.79	30.57	33.46	31.06	30.90	30.82	31.06
MnO	0.35	0.38	0.40	0.69	0.78	0.43	1.00	0.29	0.43	0.34	0.58
MgO	3.45	3.89	4.11	4.05	3.90	5.11	3.74	3.30	2.96	3.06	3.12
CaO	6.17	5.97	5.87	4.78	4.26	5.53	3.66	6.08	6.67	6.62	6.59
Na ₂ O	0.05	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K ₂ O	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00
Total	99.41	99.62	99.91	98.98	98.81	102.65	99.83	98.76	98.87	98.81	99.22

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	2.95	2.95	2.96	2.96	2.96	2.96	2.95	2.96	2.95	2.97	2.95
Al ^{iv}	0.05	0.05	0.04	0.04	0.04	0.04	0.05	0.04	0.05	0.03	0.05
Al ^{vi}	1.96	1.96	1.96	1.96	1.98	1.99	1.96	1.98	1.97	1.97	1.96
Ti	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00
Fe	2.10	2.08	2.05	2.12	2.14	1.96	2.25	2.10	2.09	2.08	2.09
Mn	0.02	0.03	0.03	0.05	0.05	0.03	0.07	0.02	0.03	0.02	0.04
Mg	0.41	0.46	0.49	0.49	0.47	0.58	0.45	0.40	0.36	0.37	0.37
Ca	0.53	0.51	0.50	0.41	0.37	0.45	0.32	0.53	0.58	0.57	0.57
Na	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Alm	68.5	67.5	66.9	69.2	70.7	64.8	73.0	69.0	68.4	68.3	68.0
% Sp	0.8	0.8	0.9	1.5	1.8	0.9	2.3	0.7	1.0	0.8	1.3
% Py	15.6	17.7	18.9	18.8	18.3	23.9	17.0	15.0	13.2	13.8	13.9
% Gr	20.9	19.9	19.5	15.5	13.8	17.7	11.4	20.9	23.4	23.2	22.7

MT98-146 Garnet (continued)

Sample	G180	G181	G182	G183	G184	G185	G186	G187	G188	G189	G190
SiO ₂	36.04	36.57	36.48	36.46	35.53	36.37	36.35	36.38	36.28	36.74	36.61
Al ₂ O ₃	21.10	21.05	20.99	21.10	21.07	20.99	21.03	20.99	20.81	21.07	20.94
TiO ₂	0.09	0.09	0.10	0.11	0.09	0.09	0.11	0.13	0.08	0.07	0.14
Cr ₂ O ₃	0.00	0.02	0.03	0.00	0.01	0.08	0.00	0.02	0.02	0.03	0.05
FeO	31.33	31.06	31.75	32.07	31.52	30.64	31.40	30.18	31.62	30.90	31.45
MnO	0.83	1.09	1.00	1.24	1.30	1.48	1.61	1.65	1.95	1.83	1.86
MgO	3.00	2.79	2.95	3.01	2.84	2.72	2.69	2.59	2.73	2.68	2.66
CaO	6.43	6.33	5.74	5.13	5.64	6.56	5.90	6.47	5.54	5.94	5.71
Na ₂ O	0.01	0.02	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00
K ₂ O	0.01	0.02	0.02	0.01	0.01	0.02	0.00	0.01	0.01	0.01	0.00
Total	98.84	99.03	99.06	99.14	98.01	98.95	99.09	98.42	99.06	99.27	99.42

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	2.93	2.96	2.95	2.95	2.92	2.95	2.95	2.96	2.95	2.97	2.96
Al iv	0.07	0.04	0.05	0.05	0.08	0.05	0.05	0.04	0.05	0.03	0.04
Al vi	1.95	1.96	1.96	1.96	1.95	1.95	1.96	1.97	1.94	1.97	1.95
Ti	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01
Cr	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Fe	2.13	2.10	2.15	2.17	2.16	2.08	2.13	2.05	2.15	2.09	2.13
Mn	0.06	0.07	0.07	0.09	0.09	0.10	0.11	0.11	0.13	0.13	0.13
Mg	0.36	0.34	0.36	0.36	0.35	0.33	0.32	0.31	0.33	0.32	0.32
Ca	0.56	0.55	0.50	0.45	0.50	0.57	0.51	0.56	0.48	0.51	0.49
Na	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Alm	68.5	68.6	70.0	70.8	69.8	67.5	69.2	67.4	69.4	68.5	69.3
% Sp	1.9	2.5	2.3	2.9	3.0	3.4	3.7	3.9	4.5	4.3	4.3
% Py	13.3	12.4	13.1	13.4	12.6	12.0	11.8	11.5	11.9	11.8	11.7
% Gr	21.9	21.8	19.3	17.0	19.1	22.7	20.0	22.7	18.5	20.3	19.2

MT98-146 Garnet (continued)

Sample	G191	G192	G193	G194	G195	G196	G197	G198	G199	G200	G201
SiO ₂	36.30	36.54	36.78	36.41	36.03	36.51	36.43	36.46	36.59	36.34	36.56
Al ₂ O ₃	20.94	20.92	20.89	20.87	20.80	20.97	21.01	21.06	20.92	20.90	20.96
TiO ₂	0.08	0.33	0.11	0.15	0.10	0.10	0.12	0.12	0.11	0.12	0.11
Cr ₂ O ₃	0.00	0.11	0.02	0.03	0.00	0.02	0.05	0.07	0.07	0.04	0.06
FeO	30.98	30.35	30.77	30.68	30.71	30.76	30.88	30.89	30.69	30.86	31.14
MnO	2.00	1.98	2.01	1.78	1.88	1.88	1.67	1.63	1.70	1.78	1.85
MgO	2.57	2.52	2.52	2.60	2.57	2.45	2.72	2.55	2.53	2.62	2.70
CaO	5.63	6.04	5.91	6.12	5.96	6.06	5.97	6.17	6.34	5.73	5.97
Na ₂ O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K ₂ O	0.00	0.01	0.02	0.00	0.02	0.02	0.01	0.00	0.00	0.02	0.03
Total	98.50	98.81	99.04	98.63	98.08	98.77	98.87	98.94	98.93	98.41	99.38

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	2.96	2.96	2.98	2.96	2.95	2.97	2.95	2.96	2.97	2.96	2.96
Al iv	0.04	0.04	0.02	0.04	0.05	0.03	0.05	0.04	0.03	0.04	0.04
Al vi	1.97	1.96	1.97	1.96	1.96	1.97	1.96	1.97	1.96	1.97	1.95
Ti	0.00	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Cr	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe	2.11	2.06	2.08	2.09	2.10	2.09	2.09	2.09	2.08	2.10	2.10
Mn	0.14	0.14	0.14	0.12	0.13	0.13	0.11	0.11	0.12	0.12	0.13
Mg	0.31	0.30	0.30	0.32	0.31	0.30	0.33	0.31	0.31	0.32	0.33
Ca	0.49	0.53	0.51	0.53	0.52	0.53	0.52	0.54	0.55	0.50	0.52
Na	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Alm	69.2	68.1	68.6	68.3	68.5	68.7	68.5	68.7	68.1	69.1	68.5
% Sp	4.7	4.7	4.8	4.2	4.4	4.4	3.9	3.8	4.0	4.2	4.3
% Py	11.4	11.2	11.1	11.5	11.4	10.8	12.1	11.3	11.1	11.7	11.9
% Gr	19.2	21.0	20.3	21.1	20.5	21.0	20.4	21.3	22.0	19.7	20.2

MT98-146 Garnet (continued)

Sample	G202	G203	G204	G205	G206	G207	G208	G209	G210	G211	G212
SiO ₂	36.32	36.54	36.57	36.53	37.05	37.17	37.00	35.52	36.64	36.77	36.81
Al ₂ O ₃	20.90	20.90	20.92	20.95	20.92	20.98	21.14	20.77	21.25	21.37	21.12
TiO ₂	0.11	0.09	0.10	0.11	0.08	0.08	0.08	0.08	0.11	0.08	0.11
Cr ₂ O ₃	0.03	0.01	0.06	0.00	0.07	0.02	0.00	0.06	0.05	0.04	0.10
FeO	30.99	31.05	30.87	31.05	30.73	31.09	30.52	31.11	30.99	30.99	30.17
MnO	1.65	1.64	1.49	0.29	0.25	0.33	0.36	1.06	0.37	0.35	0.41
MgO	2.73	2.84	3.22	3.33	3.39	3.44	3.56	3.48	3.94	3.82	3.61
CaO	6.06	5.57	5.72	6.74	6.71	5.98	6.28	5.17	5.92	5.83	6.71
Na ₂ O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
K ₂ O	0.00	0.00	0.01	0.00	0.02	0.00	0.01	0.00	0.02	0.01	0.01
Total	98.80	98.64	98.95	99.01	99.21	99.08	98.94	97.25	99.28	99.27	99.04

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	2.95	2.97	2.96	2.95	2.97	2.99	2.97	2.93	2.94	2.95	2.96
Al iv	0.05	0.03	0.04	0.05	0.03	0.01	0.03	0.07	0.06	0.05	0.04
Al vi	1.95	1.97	1.95	1.94	1.95	1.97	1.97	1.95	1.95	1.97	1.96
Ti	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.01	0.00	0.01
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Fe	2.11	2.11	2.09	2.10	2.06	2.09	2.05	2.14	2.08	2.08	2.03
Mn	0.11	0.11	0.10	0.02	0.02	0.02	0.02	0.07	0.03	0.02	0.03
Mg	0.33	0.34	0.39	0.40	0.41	0.41	0.43	0.43	0.47	0.46	0.43
Ca	0.53	0.48	0.50	0.58	0.58	0.51	0.54	0.46	0.51	0.50	0.58
Na	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Alm	68.4	69.1	67.9	67.6	67.4	68.8	67.4	69.1	67.4	67.9	66.1
% Sp	3.8	3.8	3.4	0.6	0.6	0.7	0.8	2.4	0.8	0.8	0.9
% Py	12.0	12.7	14.5	14.8	15.3	15.7	16.3	16.0	18.0	17.6	16.4
% Gr	20.7	18.9	19.2	23.2	23.2	20.4	21.6	17.3	19.8	19.6	23.2

MT98-146 Garnet (continued)

Sample	G213	G214	G215	G216	G217	G218	G219	G220	G221	G222	G223
SiO ₂	36.65	36.46	36.47	36.66	36.73	36.39	36.67	36.71	36.74	37.02	37.10
Al ₂ O ₃	21.37	21.28	21.06	21.18	21.28	21.32	21.31	21.30	21.27	21.31	21.31
TiO ₂	0.07	0.08	0.05	0.07	0.10	0.10	0.09	0.11	0.05	0.05	0.05
Cr ₂ O ₃	0.06	0.00	0.07	0.00	0.06	0.04	0.02	0.02	0.05	0.01	0.06
FeO	30.78	30.27	31.22	30.61	31.22	30.96	30.88	30.91	32.27	30.37	30.55
MnO	0.36	0.37	0.54	0.35	0.42	0.36	0.39	0.41	0.88	0.49	0.40
MgO	3.68	3.65	3.69	3.75	3.74	3.89	3.75	3.76	3.89	4.29	3.97
CaO	6.31	6.59	5.60	5.90	5.86	5.88	6.04	6.23	3.95	5.41	5.78
Na ₂ O	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K ₂ O	0.02	0.01	0.00	0.03	0.00	0.00	0.01	0.00	0.03	0.03	0.02
Total	99.30	98.71	98.70	98.55	99.42	98.95	99.15	99.45	99.11	98.97	99.24

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	2.94	2.94	2.95	2.96	2.95	2.93	2.95	2.94	2.96	2.97	2.97
Al iv	0.06	0.06	0.05	0.04	0.05	0.07	0.05	0.06	0.04	0.03	0.03
Al vi	1.96	1.96	1.96	1.97	1.96	1.96	1.96	1.95	1.98	1.98	1.98
Ti	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.00	0.00	0.00
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe	2.07	2.04	2.11	2.07	2.09	2.09	2.07	2.07	2.17	2.03	2.04
Mn	0.02	0.03	0.04	0.02	0.03	0.02	0.03	0.03	0.06	0.03	0.03
Mg	0.44	0.44	0.44	0.45	0.45	0.47	0.45	0.45	0.47	0.51	0.47
Ca	0.54	0.57	0.49	0.51	0.50	0.51	0.52	0.54	0.34	0.46	0.50
Na	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Alm	67.2	66.4	68.6	67.7	68.1	67.6	67.6	67.2	71.5	66.8	67.2
% Sp	0.8	0.8	1.2	0.8	0.9	0.8	0.9	0.9	2.0	1.1	0.9
% Py	16.7	16.6	16.9	17.3	17.0	17.8	17.1	17.0	18.1	20.2	18.4
% Gr	21.4	22.7	18.7	20.1	19.6	19.7	20.4	21.0	12.6	18.0	19.5

MT98-146 Garnet (continued)

Sample	G224	G225	G226	G227	G228	G229	G230	G231	G232	G233	G234
SiO ₂	37.07	36.77	36.73	36.82	37.05	36.76	36.65	36.94	36.91	36.06	36.65
Al ₂ O ₃	21.22	21.20	21.20	21.16	21.17	21.19	21.10	21.27	21.14	20.98	21.08
TiO ₂	0.05	0.60	0.08	0.09	0.10	0.12	0.09	0.07	0.06	0.08	0.12
Cr ₂ O ₃	0.01	0.03	0.00	0.07	0.06	0.03	0.02	0.02	0.03	0.08	0.06
FeO	31.33	30.65	30.83	31.09	30.98	31.21	30.78	30.76	31.08	31.65	31.06
MnO	0.33	0.35	0.40	0.31	0.31	0.47	0.61	0.55	0.75	2.52	0.81
MgO	3.69	3.38	3.24	2.97	3.15	3.17	2.94	2.98	3.06	2.44	3.05
CaO	5.77	6.11	6.63	6.73	6.67	6.41	6.68	6.77	5.96	4.82	6.28
Na ₂ O	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K ₂ O	0.02	0.00	0.01	0.01	0.00	0.01	0.02	0.02	0.00	0.01	0.00
Total	99.50	99.09	99.12	99.26	99.48	99.37	98.88	99.39	99.00	98.64	99.12

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	2.97	2.95	2.96	2.96	2.97	2.96	2.96	2.96	2.97	2.95	2.96
Al iv	0.03	0.05	0.04	0.04	0.03	0.04	0.04	0.04	0.03	0.05	0.04
Al vi	1.97	1.96	1.97	1.97	1.97	1.96	1.97	1.98	1.98	1.97	1.96
Ti	0.00	0.04	0.00	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.01
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Fe	2.10	2.06	2.07	2.09	2.08	2.10	2.08	2.06	2.09	2.16	2.10
Mn	0.02	0.02	0.03	0.02	0.02	0.03	0.04	0.04	0.05	0.17	0.06
Mg	0.44	0.40	0.39	0.36	0.38	0.38	0.35	0.36	0.37	0.30	0.37
Ca	0.49	0.53	0.57	0.58	0.57	0.55	0.58	0.58	0.51	0.42	0.54
Na	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Alm	68.7	68.3	67.7	68.6	68.2	68.5	68.1	67.9	69.2	70.8	68.5
% Sp	0.7	0.8	0.9	0.7	0.7	1.1	1.4	1.3	1.7	6.0	1.8
% Py	16.8	15.5	14.5	13.2	14.1	14.1	13.1	13.3	13.8	10.8	13.6
% Gr	19.3	21.1	23.0	23.5	23.2	22.0	23.4	23.7	20.5	16.0	21.6

MT98-146 Garnet (continued)

Sample	G235	G236	G237	G238	G239	G240	G241	G242	G243	G244	G245
SiO ₂	36.83	36.63	36.72	36.49	37.12	36.82	37.13	36.81	36.50	36.61	36.64
Al ₂ O ₃	20.92	21.19	21.04	21.21	21.22	21.19	21.34	21.31	21.14	21.23	21.13
TiO ₂	0.14	0.12	0.12	0.05	0.06	0.06	0.02	0.06	0.05	0.05	0.00
Cr ₂ O ₃	0.03	0.02	0.05	0.02	0.05	0.04	0.09	0.00	0.00	0.05	0.00
FeO	31.13	30.91	31.17	31.69	31.35	32.66	31.18	31.94	32.36	31.86	32.19
MnO	0.89	0.49	0.41	0.65	0.45	0.58	0.39	0.73	1.73	0.74	0.74
MgO	2.83	3.02	3.19	3.07	3.92	4.12	4.58	4.10	3.39	3.90	3.83
CaO	6.52	6.65	6.45	5.87	5.33	3.87	4.63	4.18	3.78	4.42	4.14
Na ₂ O	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K ₂ O	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.03	0.01	0.00
Total	99.29	99.04	99.15	99.04	99.50	99.34	99.38	99.15	98.97	98.87	98.66

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	2.97	2.95	2.96	2.95	2.97	2.96	2.96	2.96	2.96	2.95	2.96
Al iv	0.03	0.05	0.04	0.05	0.03	0.04	0.04	0.04	0.04	0.05	0.04
Al vi	1.96	1.97	1.96	1.97	1.97	1.97	1.97	1.98	1.98	1.97	1.98
Ti	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Fe	2.10	2.08	2.10	2.14	2.10	2.19	2.08	2.15	2.19	2.15	2.18
Mn	0.06	0.03	0.03	0.04	0.03	0.04	0.03	0.05	0.12	0.05	0.05
Mg	0.34	0.36	0.38	0.37	0.47	0.49	0.55	0.49	0.41	0.47	0.46
Ca	0.56	0.57	0.56	0.51	0.46	0.33	0.40	0.36	0.33	0.38	0.36
Na	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Alm	68.5	68.2	68.5	69.9	68.7	71.7	68.3	70.4	71.9	70.5	71.4
% Sp	2.0	1.1	0.9	1.5	1.0	1.3	0.9	1.7	4.0	1.7	1.7
% Py	12.5	13.5	14.3	13.7	18.1	19.2	21.8	19.2	15.5	18.2	17.8
% Gr	22.5	23.1	22.2	19.9	17.6	12.2	14.9	13.4	12.1	14.3	13.3

MT98-146 Garnet (continued)

Sample	G246	G247	G248	G249	G250	G251	G252	G253	G254	G255	G256
SiO ₂	36.61	36.78	36.78	36.72	37.56	37.68	37.69	37.41	37.60	37.51	37.69
Al ₂ O ₃	21.24	21.17	21.29	21.20	21.31	21.74	21.61	21.51	21.71	21.62	21.84
TiO ₂	0.02	0.04	0.06	0.07	0.10	0.03	0.09	0.14	0.10	0.15	0.04
Cr ₂ O ₃	0.04	0.11	0.02	0.02	0.04	0.03	0.04	0.08	0.00	0.05	0.03
FeO	32.12	32.16	32.72	32.77	30.81	30.77	30.22	30.70	31.00	30.60	31.38
MnO	0.89	0.50	0.81	2.01	0.40	0.34	0.43	0.44	0.86	0.35	0.93
MgO	3.57	4.34	3.99	3.22	3.60	3.62	3.70	3.61	3.24	3.51	2.95
CaO	4.05	4.04	3.81	3.59	6.00	6.01	6.27	6.44	6.18	6.25	6.16
Na ₂ O	0.00	0.00	0.00	0.00	0.01	0.00	0.03	0.00	0.00	0.00	0.00
K ₂ O	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.02	0.00	0.00
Total	98.54	99.15	99.49	99.61	99.83	100.22	100.08	100.33	100.71	100.05	101.03

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	2.97	2.96	2.95	2.96	2.99	2.98	2.98	2.96	2.97	2.97	2.97
Al iv	0.03	0.04	0.05	0.04	0.01	0.02	0.02	0.04	0.03	0.03	0.03
Al vi	1.99	1.96	1.97	1.98	1.98	2.01	2.00	1.97	1.99	1.99	2.00
Ti	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.00
Cr	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Fe	2.18	2.16	2.20	2.21	2.05	2.03	2.00	2.03	2.05	2.03	2.07
Mn	0.06	0.03	0.06	0.14	0.03	0.02	0.03	0.03	0.06	0.02	0.06
Mg	0.43	0.52	0.48	0.39	0.43	0.43	0.44	0.43	0.38	0.41	0.35
Ca	0.35	0.35	0.33	0.31	0.51	0.51	0.53	0.55	0.52	0.53	0.52
Na	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Alm	72.0	70.5	71.9	72.6	68.0	68.0	66.7	67.0	68.0	67.7	69.0
% Sp	2.1	1.1	1.8	4.7	0.9	0.8	1.0	1.0	2.0	0.8	2.1
% Py	16.6	20.5	18.5	14.6	16.5	16.6	17.1	16.3	14.5	16.1	13.1
% Gr	13.2	12.8	12.0	11.3	20.4	20.5	21.6	21.9	21.0	21.5	21.0

MT98-146 Garnet (continued)

Sample	G257	G258	G259	G260	G261	G262	G263	G264	G265	G266	G267
SiO ₂	37.67	37.18	37.30	37.71	37.84	37.69	37.28	37.55	37.30	37.75	37.54
Al ₂ O ₃	21.69	21.79	21.38	21.58	21.45	21.98	21.54	21.39	21.32	21.39	21.59
TiO ₂	0.10	0.07	0.11	0.09	0.10	0.06	0.08	0.08	0.11	0.04	0.12
Cr ₂ O ₃	0.03	0.04	0.05	0.04	0.04	0.07	0.07	0.06	0.07	0.02	0.07
FeO	31.45	31.63	31.86	31.51	31.34	31.19	31.29	30.97	31.37	31.60	31.85
MnO	0.70	0.76	1.05	0.66	0.91	0.90	0.33	0.37	1.46	1.16	0.47
MgO	3.07	2.86	2.81	3.07	2.83	2.83	3.35	3.36	2.57	2.62	2.94
CaO	6.20	5.81	6.11	6.40	6.31	6.31	6.25	6.49	6.27	6.57	6.41
Na ₂ O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K ₂ O	0.01	0.01	0.00	0.03	0.01	0.03	0.02	0.00	0.01	0.04	0.02
Total	100.92	100.15	100.67	101.09	100.83	101.06	100.21	100.28	100.48	101.18	101.01

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	2.97	2.96	2.97	2.98	2.99	2.97	2.96	2.98	2.97	2.98	2.97
Al iv	0.03	0.04	0.03	0.02	0.01	0.03	0.04	0.02	0.03	0.02	0.03
Al vi	1.99	2.01	1.97	1.98	1.99	2.01	1.98	1.98	1.98	1.98	1.98
Ti	0.01	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.01
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe	2.08	2.11	2.12	2.08	2.07	2.06	2.08	2.05	2.09	2.09	2.11
Mn	0.05	0.05	0.07	0.04	0.06	0.06	0.02	0.03	0.10	0.08	0.03
Mg	0.36	0.34	0.33	0.36	0.33	0.33	0.40	0.40	0.31	0.31	0.35
Ca	0.52	0.50	0.52	0.54	0.53	0.53	0.53	0.55	0.54	0.56	0.54
Na	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Alm	69.0	70.4	69.6	68.7	69.1	69.0	68.6	67.8	69.0	68.9	69.6
% Sp	1.6	1.7	2.4	1.5	2.1	2.0	0.7	0.8	3.4	2.6	1.0
% Py	13.6	12.8	12.3	13.5	12.5	12.5	15.1	15.1	11.2	11.4	13.0
% Gr	21.1	19.8	20.6	21.8	21.7	21.8	21.3	22.3	21.5	22.5	21.9

MT98-146 Garnet (continued)

Sample	G268	G269	G270	G271	G272	G273	G274	G275	G276	G277	G278
SiO ₂	37.56	37.91	37.78	37.53	37.57	37.65	37.66	37.94	37.51	37.86	37.65
Al ₂ O ₃	21.76	21.69	21.62	21.60	21.61	21.65	21.73	22.03	21.85	21.57	21.88
TiO ₂	0.11	0.04	0.13	0.07	0.11	0.06	0.09	0.10	0.12	0.07	0.05
Cr ₂ O ₃	0.02	0.00	0.02	0.04	0.08	0.08	0.04	0.10	0.00	0.08	0.03
FeO	30.90	31.44	31.51	31.30	31.17	31.12	31.36	31.41	30.68	30.54	30.79
MnO	0.59	0.67	0.50	0.46	0.41	0.29	0.39	0.48	0.37	0.45	0.45
MgO	3.02	3.13	3.12	3.04	3.22	3.47	3.46	3.60	3.91	4.07	4.26
CaO	7.08	6.34	6.54	6.33	6.38	6.08	6.41	6.01	6.12	5.45	5.59
Na ₂ O	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.03	0.00	0.01
K ₂ O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Total	101.03	101.23	101.22	100.35	100.53	100.42	101.13	101.67	100.60	100.11	100.71

Number of cations in formula based on n oxygens

n	12	12	12	12	12	12	12	12	12	12	12
Si	2.96	2.98	2.97	2.98	2.97	2.98	2.96	2.96	2.96	2.99	2.96
Al iv	0.04	0.02	0.03	0.02	0.03	0.02	0.04	0.04	0.04	0.01	0.04
Al vi	1.98	1.99	1.98	2.00	1.99	2.00	1.98	1.99	1.99	2.00	1.99
Ti	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.01	0.01	0.00	0.00
Cr	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.01	0.00
Fe	2.04	2.07	2.07	2.08	2.06	2.06	2.06	2.05	2.02	2.02	2.03
Mn	0.04	0.04	0.03	0.03	0.03	0.02	0.03	0.03	0.02	0.03	0.03
Mg	0.36	0.37	0.37	0.36	0.38	0.41	0.41	0.42	0.46	0.48	0.50
Ca	0.60	0.53	0.55	0.54	0.54	0.51	0.54	0.50	0.52	0.46	0.47
Na	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Alm	67.2	68.6	68.6	69.1	68.5	68.6	68.0	68.3	66.9	67.5	66.9
% Sp	1.3	1.5	1.1	1.0	0.9	0.6	0.9	1.1	0.8	1.0	1.0
% Py	13.3	13.9	13.8	13.6	14.4	15.8	15.4	16.2	17.9	19.1	19.8
% Gr	24.6	21.5	22.3	21.8	21.9	20.7	21.7	20.1	20.6	18.3	18.5

MT98-146 Garnet (continued)

Sample	G279	G280	G281
SiO ₂	37.78	37.94	37.19
Al ₂ O ₃	22.21	22.01	21.68
TiO ₂	0.07	0.05	0.02
Cr ₂ O ₃	0.12	0.03	0.06
FeO	31.08	31.48	32.73
MnO	0.29	0.33	0.84
MgO	5.57	5.17	3.74
CaO	3.67	3.70	3.60
Na ₂ O	0.00	0.01	0.00
K ₂ O	0.00	0.01	0.03
Total	100.78	100.74	99.89

Number of cations in formula based on n oxygens

n	12	12	12
Si	2.95	2.97	2.97
Al iv	0.05	0.03	0.03
Al vi	2.00	2.00	2.01
Ti	0.00	0.00	0.00
Cr	0.01	0.00	0.00
Fe	2.03	2.06	2.18
Mn	0.02	0.02	0.06
Mg	0.65	0.60	0.45
Ca	0.31	0.31	0.31
Na	0.00	0.00	0.00
K	0.00	0.00	0.00
% Alm	67.6	68.8	73.0
% Sp	0.6	0.7	1.9
% Py	27.5	25.2	17.5
% Gr	11.4	11.6	11.4

MT98-146 Garnet (continued)

Sample	G279	G280	G281
SiO ₂	37.78	37.94	37.19
Al ₂ O ₃	22.21	22.01	21.68
TiO ₂	0.07	0.05	0.02
Cr ₂ O ₃	0.12	0.03	0.06
FeO	31.08	31.48	32.73
MnO	0.29	0.33	0.84
MgO	5.57	5.17	3.74
CaO	3.67	3.70	3.60
Na ₂ O	0.00	0.01	0.00
K ₂ O	0.00	0.01	0.03
Total	100.78	100.74	99.89

Number of cations in formula based on n oxygens

n	12	12	12
Si	2.95	2.97	2.97
Al iv	0.05	0.03	0.03
Al vi	2.00	2.00	2.01
Ti	0.00	0.00	0.00
Cr	0.01	0.00	0.00
Fe	2.03	2.06	2.18
Mn	0.02	0.02	0.06
Mg	0.65	0.60	0.45
Ca	0.31	0.31	0.31
Na	0.00	0.00	0.00
K	0.00	0.00	0.00
% Alm	67.6	68.8	73.0
% Sp	0.6	0.7	1.9
% Py	27.5	25.2	17.5
% Gr	11.4	11.6	11.4

NOTE TO USERS

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UMI

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81°44'

Hanging Wall

Hurwitz Group

Kinga Formation

(Whiterock Member) Quartz arenite to quartz pebble conglomerate, white to buff weathering.

Watterson Formation

Phyllitic arkose to shale; white to beige weathering with abundant sericite locally. Beds typically 2 - 5 cm.

Dolostone; brown to buff-weathering locally with fine laminations (1 - 3 mm).

Kaminak greenstone belt

Diorite; medium to coarse grained, moderately to strongly lineated. Lineation defined by hornblende and/or actinolite.

Metagreywacke; grey to buff, fine-grained sandy and muddy beds, 1 - 10 cm thick. Locally graded bedding.

Metavolcaniclastic sedimentary rocks, predominantly intermediate composition, clasts range from 2 mm - 20 cm. Typically 1 - 3 cm thick beds (up to 1m locally). Unit characterized by a strong, subhorizontal lineation, defined by clast stretching and metamorphic mineral growth.

Yathkyed greenstone belt

Yellow granite; massive, fine-grained granite, cut by abundant quartz, carbonate, and pyrite veins, and variably replaced by pyrite, chalcopryite. Commonly rusty on weathered surface. Locally contains up to 80% pyrite.

Carnecksluck intrusive suite

Biotite tonalite, medium grained, weakly to strongly foliated biotite and chlorite tonalite to granodiorite, locally cut by leucocratic granite veins along and across the foliation.

Hornblende gabbro; medium to coarse grained, massive to moderately foliated hornblende gabbro to quartz diorite.

Felsic metavolcanic rocks, thinly layered (1 - 10cm), locally rusty-weathering tuffs (?), Commonly with rounded quartz eyes and plagioclase phenocrysts. Felsic volcanic and quartz-feldspar porphyry clasts present locally. Unit is

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Symbols

Trace of chlorite schistosity along the Nowyak shear zone

Yathkyed greenstone belt

Yellow granite; massive, fine-grained granite, cut by abundant quartz, carbonate, and pyrite veins, and variably replaced by pyrite, chalcopryite. Commonly rusty on weathered surface. Locally contains up to 80% pyrite.

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Felsic metavolcanic rocks, thinly layered (1 - 10cm), locally rusty-weathering tuffs (?), Commonly with rounded quartz eyes and plagioclase phenocrysts. Felsic volcanic and quartz-feldspar porphyry clasts present locally. Unit is strongly sericitized.

Mafic metavolcanic rocks; dominated by massive and pillowed mafic flows, locally with thinly-bedded mafic sediments (tuffs?).

Nowyak Shear Zone

Mafic metavolcanic rocks; chlorite schist to chlorite mylonite; fine to medium grained, strongly foliated, strong lineation defined by pulled apart plagioclase. Kinematic indicators suggest top-down-to-the-north sense of displacement.

Variably strained amphibolite (actinolite, hornblende, biotite, plagioclase) preserved in low grade enclaves within the Nowyak shear zone. Moderately foliated, strong mineral lineation defined by orientation of amphibole.

Footwall

Biotite-muscovite schist; strongly schistose.

Nowyak metagranite

Biotite muscovite metagranite to granitic gneiss; variably strained; strongly foliated, moderate lineation defined by stretching of plagioclase feldspar. Pale pink on fresh and weathered surfaces.

Stonecutter supracrustal unit

Psamitic to pelitic schist; amphibolite to amphibole gneiss; interlayered at a scale of 5 to 20 m. Strongly foliated; mineral lineation defined by hornblende.

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Map 1: Structural map for the Nowya
Parts of NTS AR-30/65G,H, modified

the Nowyak complex and surrounding rocks, Nunavut, (H, modified from Relf, C., 1996 (EGS 1996-19).

Symbols

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ing rocks, Nunavut, Canada.
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Symbols

Trace of chlorite schistosity along the Nowyak shear zone

Bodies of water

Assumed contact

Limit of mapping

Trace of late brittle fault

Foliation symbol with dip

Lineation symbol with plunge

Fold axis with plunge

Trace of upright antiform

Top-down- to-the-north kinematic indicator

Top-down-to-the-south kinematic indicator

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UMI

Hanging Wall

Hurwitz Group

Kinga Formation

(Whiterock Member) Quartz arenite to quartz pebble conglomerate, white to buff weathering.

Watterson Formation

Phyllitic arkose to shale; white to beige weathering with abundant sericite locally. Beds typically 2 - 5 cm.

Dolostone; brown to buff-weathering locally with fine laminations (1 - 3 mm).

Kaminak greenstone belt

Wd

Nd

Wd

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MT98-158
98-157

MT98-138

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Mv

MT98-101 MT98-102

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Kaminak greenstone belt

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GW

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Yellow granite; massive, fine-grained granite, cut by abundant quartz, carbonate, and pyrite veins, and variably replaced by pyrite, chalcopyrite. Commonly rusty on weathered surface. Locally contains up to 80% pyrite.

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Hornblende gabbro; medium to coarse grained, massive to moderately foliated hornblende gabbro to quartz diorite.

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Fv

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Mv

Mafic metavolcanic rocks; dominated by massive and pillowed mafic flows, locally with thinly-bedded mafic sediments (tuffs?).

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Footwall

Sch

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Nowyak metagranite

Bmgr

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Map 2: Sample location map for t
Canada. Parts of NTS AR-30/65

Location map for the Nowyak complex and surrounding areas of NTS AR-30/65G,H, modified from Relf, C., 1996 (EC)

plex and surrounding rocks, Nunavut,
om Relf, C., 1996 (EGS 1996-19).

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1:50,

Symbols

Bodies of water

Assumed contact

Limit of mapping

PT sample location

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Geochemistry sample location

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Symbols

Bodies of water

Assumed contact

Limit of mapping

PT sample location

^{39}Ar - ^{40}Ar geochronology sample location

SHRIMP geochronology sample location

Geochemistry sample location

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