**MINERALOGY AND GEOCHEMISTRY OF PEGMATITES ON MOUNT BEGBIE,
BRITISH COLUMBIA**

by

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Abstract

The pegmatite field on Mount Begbie, near Revelstoke, B.C., is a Li-rich pegmatite field in the southern Canadian Cordillera that is relatively well-known among prospectors, but until now, under-studied by academics. Mapping the pegmatite field on the northeastern slope of the mountain revealed a dense population of S-type granitic pegmatites belonging to the LCT family with diverse ranges of mineralogy corresponding to barren, beryl-columbite, beryl-columbite-phosphate, and lepidolite-subtype compositions. Typically, the pegmatites are not strongly metamorphosed and show only rare foliation, meaning they primarily postdate the exhumation of the Thor-Odin Culmination that occurred during the Late Paleocene to Early Eocene. They are likely related to other granitic bodies (i.e., the Ladybird granite suite) resulting from the exhumation event rather than any other known intrusions in the Monashee complex. The dikes in the study area are elongate, with most at least 10 m long and are usually not more than one meter wide; the largest is approximately 520 m long and 10 m wide. Orientations of the pegmatites are dictated in part by conjugate shear planes developed in the host rock prior to the emplacement of the dikes; nearly all strike between 295° and 330° and have a subvertical dip. Fractionation is variable within the most primitive of the pegmatites and it may be controlled by localized fluid accumulation or the composition of the original source rock. Despite variability, fractionation within the pegmatite field increases from the southeast to the northwest, suggesting the source pluton may be located to the southeast of the study area at depth. Detailed examination of the minerals tourmaline, sekaninaite, beryl, rare-element oxides, and zircon as well as the mostly qualitative study of phosphates and other minerals provides insight into the geochemistry and mineralogy of the individual dikes. The results suggest that some of the primitive dikes are more fractionated than they appear and highlight other pegmatites as having unusual compositions for typical beryl-columbite and beryl-columbite-phosphate-subtype pegmatites. Elevated contents of Be and Li in sekaninaite and the presence of qitianlingite in the Mount Begbie pegmatite field are somewhat unique compared to other cordierite and rare-element oxide localities worldwide.

Preface

This thesis is original, unpublished, independent work by the author, Andrea Dixon with assistance from Stefan Kruse in adapting the base geological map and from Jan Cempírek in data interpretation in Chapter 5 and 6.

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Chapter 1: Introduction

1.1 Pegmatites

While pegmatites are not typically a subject of daily discourse, they are commonly part of modern daily life. They are important sources of raw materials for humble ceramic and glass objects (feldspars) to the exotic-sounding ingredients of modern electronic devices (rare earth elements and high field strength elements). A myriad of gemstones worn for special events or evenings out can also be sourced from pegmatites.

The term “pegmatite” typically denotes coarse grain sizes in intrusive igneous rocks. To form such coarse grain sizes, a special set of conditions is necessary which leads to other features beyond a coarse texture. For the purposes here, the term pegmatite follows the definition set out by London (2008), “an essentially igneous rock, commonly of granitic composition, that is distinguished from other igneous rocks by its extremely coarse but variable grain size, or by an abundance of crystals with skeletal, graphic, or other strongly directional growth habits. Pegmatites occur as sharply bounded homogeneous to zoned bodies within igneous or metamorphic host rocks.”

1.1.1 Describing and Classifying Pegmatites

When a pegmatite field is discovered, describing and classifying the field and the individual pegmatites it contains is beneficial for scientific and economic purposes – from understanding Earth processes to sourcing valuable commodities. The initial step for any classification scheme is to identify the igneous rock type that the pegmatites most closely resemble. Granitic pegmatites are by far the most common but pegmatites can arise from magmas of all compositions; e.g., the next most abundant pegmatites have gabbroic compositions (London 2008).

The following is an examination of the internal structures of the pegmatites, as the internal structures determine the distribution of minerals within the pegmatites. On an individual scale, pegmatites may be simple, zoned, or complex. On the scale of the pegmatite field, such examinations may also show a regional distribution of some minerals (Simmons *et al.* 2003, Simmons & Webber 2008).

Granitic pegmatite fields are further delineated by geological location in addition to indicators given by their mineralogy, i.e., paragenetic indicators (Černý & Ercit 2005, Simmons & Webber 2008). The current classification scheme uses some of these indicators to group granitic pegmatites into five classes: abyssal, muscovite, muscovite-rare element, rare-element, and miarolitic. This scheme is generally widely accepted, although some researchers have noted a greater diversity in pegmatites and pegmatite genesis as well as a lack of correlation between depth and geochemistry as outlined by the scheme (Martin & De Vito 2005, Simmons & Webber 2008). Despite its defects and lack of a better alternative, the current scheme provides a common framework for pegmatite research around the world.

With the exception of the muscovite class, each of the classes mentioned in the scheme can be further divided into subclasses and families; some of these are commonly split into types and subtypes. For example, pegmatites in the rare-element and miarolitic classes can be grouped into three families based on the principal rare-elements present: LCT (lithium – cesium – tantalum), NYF (niobium – yttrium – fluorine), and mixed LCT + NYF (pegmatites with geochemical signatures that appears to be a hybrid of the LCT and NYF families). The LCT family contains two dominant subclasses, eight types, and seven subtypes (Černý & Ercit 2005). For further information on pegmatite classification, please see Černý (1991) and Černý & Ercit (2005). Of interest to this thesis are granitic pegmatites of the rare-element class and the LCT family.

Rare-element pegmatites are thought to have formed from granite magmas at low to moderate depths and at relatively low to moderate temperatures. LCT family pegmatites are often assumed to be linked to granite plutons formed from the partial melting of metamorphic rocks which were derived from sedimentary and igneous rocks (S-, I-, and mixed S + I type granites). Other researchers have suggested that some pegmatites could be a product of direct anatexis of the same rock types. Granitic magmas from these sources have slightly higher amounts of Al_2O_3 in comparison to the combined quantities of Na_2O , K_2O , and CaO in bulk geochemistry determinations (Černý & Ercit 2005, London 2008, Simmons & Webber 2008).

1.1.2 Pegmatite Formation

Although the current classification scheme proposes general conditions for pegmatite formation, the process is more complex than cooling magma at a specific depth and temperature. It has long been held – and is still widely accepted – that pegmatites are the result of fractional

crystallization from granites, a similar concept to ordinary magma evolution from a mafic to felsic melt, albeit not nearly as dramatic (Simmons *et al.* 2003, London 2008). Other current theories of pegmatite formation hold that pegmatites can result from direct anatexis (as previously mentioned), precipitation from hydrothermal fluids, crystallization from residual magmatic fluids influenced by hydrothermal fluids, crystallization from a hydrous silicate gel (particularly in the latter stages of pegmatite formation), and/or crystallization from a flux-rich silicate magmas (Simmons & Webber 2008, Thomas *et al.* 2012). The following is a summary of London's (2008) model of pegmatites which discusses how various mineral phases and textures could be the result of fractional crystallization from granitic magma.

Initially, it was assumed that the coarse textures seen in pegmatites were the result of a relatively stable, extra-long, and slow cooling process, in the same manner that large crystals typically form in igneous rocks. However, this assumption could not explain all of the textures seen, such as the graphic intergrowth of quartz and feldspar, commonly known as graphic granite, or the formation of fine-grained layers and related dikes called aplites, all of which can be present within the same pegmatite (Fenn 1986, Rockhold *et al.* 1987, London 2008, Simmons & Webber 2008). To explain all of these textures, a new explanation was gradually created starting with fractional crystallization and involving rapid crystallization from volatile-enriched magma and strong undercooling.

During fractional crystallization, common rock-forming elements are readily removed early in the process, leaving behind incompatible elements and molecules: F, Cl, Li, Na, K, Rb, Cs, Be, H₂O, OH⁻, CO₂, HCO₃⁻, CO₃²⁻, SO₄²⁻, PO₄³⁻, and H₃BO₃ (Thomas *et al.* 2012). These elements and molecules play a role similar to that of a fluxing agent, encouraging the diffusion of other elements through the magma. These incompatible elements and molecules may also eventually crystallize and re-dissolve, creating further fluctuations in the geochemistry of the melt, allowing a potentially diverse set of minerals to form (Simmons *et al.* 2003, London 2008, Thomas *et al.* 2012).

Undercooling happens when a liquid is subjected to temperatures below its freezing point but does not freeze. As a pegmatite magma propagates away from its parent magma, it enters rocks that are progressively cooler and at shallower depths. This cooler and shallower environment can prevent a viscous, highly evolved granitic magma from flowing despite being

liquid. In this solid-like state, the overall temperature of the magma can drop below the point in which one would expect the magma to freeze.

Once the magma is in this state, the combined effects of undercooling and an incompatible element and molecule-enriched magma allows for quick crystallization. Cooling from the outside inwards, a narrow boundary may form between the growing crystals and the central magma body allowing for the exchange of ions; incompatible elements and molecules are expelled from the growing crystals and compatible elements are extracted from the magma and incorporated into the crystals. Such a boundary layer may become oversaturated with incompatible elements and molecules dissolving some of the recently formed crystals. Crystals that are not dissolved continue to grow, with some reaching the large crystal sizes for which pegmatites are known.

Near the end of crystallization, the central portion of the magma could be entirely composed of the boundary layer fluid. This fluid may be expelled from the center, partially dissolving and replacing existing crystals with new minerals; crystallizing into unique mineral assemblages; or it might be completely depleted in elements – both compatible and incompatible – and will crystallize as pure quartz.

In contrast to the model put forth by London (2008), other researchers suggest that a highly evolved granitic magma may have a low viscosity and that undercooling as well as a narrow boundary layer are not necessarily important. Slight variations in the temperature and pressure conditions for a highly evolved magma with low viscosity could be enough to promote pegmatite formation (Thomas *et al.* 2012).

The existing models do address some of the more fundamental questions regarding formation, textures, and crystal sizes of pegmatites in comparison to the original hypothesis that pegmatites are the product of long and slow crystallization periods. More knowledge about pegmatites is needed to confirm the London (2008) model as well as to develop and expand upon others regarding pegmatite formation.

1.2 Mount Begbie Pegmatites

Mount Begbie is a mountain within the Canadian Cordillera, located approximately 12 km south of Revelstoke, British Columbia. A study of the pegmatite field on Mount Begbie presents an opportunity to add to current pegmatite knowledge, as the pegmatites on Mount Begbie have

not been scientifically studied. This study is also an opportunity to expand on the limited scientific knowledge of pegmatites of the Canadian Cordillera.

In general, pegmatites within the Canadian portion of the North American Cordillera have largely been overlooked, even though Cordilleran pegmatites in the United States have been significant producers of strategic raw minerals and gemstones for over a century, such as the Harding Mine in New Mexico as well as the Pala and Mesa Grande districts in San Diego County, California (London 2008). Highly fractionated pegmatite fields in northwestern Canada have been only recently discovered and described, such as the Little Nahanni Pegmatite Group and the O'Grady Batholith in the Northwest Territories (e.g., Groat *et al.* 2003, Ercit *et al.* 2003). This is the first comprehensive study of pegmatites within this section of the Canadian Cordillera.

Unlike the Little Nahanni Pegmatite Group and the O'Grady Batholith pegmatites, the Mount Begbie pegmatites are relatively well known, having been noted since at least the late 1800s and qualitatively described by prospectors and mineral collectors for over half a century (Jones 1959). These reports describe the dikes as being typically homogeneous, lenticular, sill-like sheets, typically not more than 2 meters wide, that sometimes cut across bedding planes, faults, and fractures. In terms of minerals, the dikes were said to have abundant black tourmaline up to 5 cm long, with one or two dikes containing black, red, and green tourmaline along with green beryl, garnet, and lepidolite. Additionally, prospectors and mineral collectors observed rose quartz, prominent feldspar crystals up to 40 cm long, and blocky, opaque white to blue-green beryl crystals up to 15 cm long with occasional transparent yellow or blue patches in some of the dikes (Jones 1959, B. Wilson, pers. commun., H. Hyder, pers. commun., & D. Javorsky, pers. commun.).

Despite a long history of mineral collecting, scientifically gathered information on the pegmatites is scarce, much like information for other Canadian Cordillera pegmatites. The dearth of research partially stems from a lack of accessibility; until recently, the majority of the pegmatites have been covered by Mount Begbie's glacier and snowfield. The existing research is primarily found within papers about the regional geology and tectonic history of the region. In most cases, the information is limited to descriptions of "conformable" versus "unconformable" relations to their host rocks in efforts to understand regional tectonism and metamorphism (e.g., Vanderhaege *et al.* 1999, Johnston *et al.* 2000). Rarely, physical and geochemical descriptions

of the granitic bodies themselves have appeared. These few papers have mentioned that they have an S-type composition, that in some cases black tourmaline may comprise up to 5% of the pegmatite volume and be up to 10 cm long, that aplitic portions contain more abundant tourmaline, and one geochemical sample contained 13 ppm Li (Craig 1966, Reesor & Moore 1971, Mulligan 1972, Hinchey & Carr 2008).

1.2.1 Scope and Objectives

In light of this dearth of information, this is the first systematic scientific study of the Mount Begbie pegmatites. The study area was selected on the basis of the observations made by prospectors, mineral collectors, and previous researchers. The area is located on a relatively gentle slope between the tree line to the north, the toe of Mount Begbie's glacier to the south, and lateral moraines to the east and west on the northeastern slope and encompasses nearly 0.5 km² (Fig. 2.1).

With the area selected, the objectives for this study are to: (1) locate, map, and sample pegmatites located there; (2) characterize the pegmatites and related granitic bodies from field observations and hand samples as to their physical dimensions and whether or not they are homogeneous, zoned, or complex; (3) analyze their mineralogy and geochemistry to determine the correct pegmatite class, family, and regional zonation trends; (4) identify the type of parent magma, a possible source pluton, and the pegmatites' place within the tectono-magmatic history of the region; and (5) based on the results, comment on the economic potential for both strategic raw materials and gemstones for these North American Cordillera pegmatites.

Chapter 2: Regional Geology

2.1 Geological Setting and History

Mount Begbie is part of the Shuswap Metamorphic Complex located in the southern part of the Omineca Belt of the Canadian Cordillera (Okulitch 1984, Wheeler & McFeely 1991). The pegmatites are hosted in rocks belonging to the cover assemblage of the Monashee complex in the northern part of the Thor-Odin culmination (Fig. 2.1) (Kruse *et al.* 2005).

The Cordillera formed as a result of the accretion of terranes along the western edge of ancestral North America; the Omineca Belt is the section of the Cordillera comprised of both ancestral North America and the innermost of the accreted terranes (Carr 1991, Hinchey *et al.* 2006). By the Middle Jurassic, the accretion of terranes resulted in crustal thickening and metamorphism of the region throughout the Cretaceous (Hinchey *et al.* 2006, Johnson 2006). In the southern Omineca, regional extension and uplift during the Eocene led to the exposure of basement rocks, including those of the Shuswap Metamorphic Complex (Hinchey *et al.* 2006, Norlander *et al.* 2002).

The Monashee complex is the lowest structural unit of the Shuswap Metamorphic Complex and exposes ancestral North America. It contains two culminations, the Frenchman Cap in the north and the Thor-Odin in the south, both comprised of gneiss cores and a cover sequence of unconformably overlying metasediments (Norlander *et al.* 2002, Kruse & Williams 2007). Both the core and the cover sequence of the Thor-Odin culmination have experienced considerable deformation, high-grade metamorphism, late Paleocene-early Eocene anatexis, and Eocene brittle faulting (Johnston *et al.* 2000, Kruse & Williams 2005, Hinchey *et al.* 2006).

Figure 2.1: Setting of the study area within the Thor-Odin culmination and in context with the Canadian Cordillera. For more details of the study area, please see Fig. 3.1 and Appendix B.1. Figure modified after Kruse *et al.* (2005) and Kruse (2007).

2.2 P-T-t Conditions of Metamorphic Overprint

Between 50-60 Ma, the Thor-Odin culmination experienced rapid exhumation and decompression (Norlander *et al.* 2002, Spalla *et al.* 2011). For discussions of the possible

mechanisms regarding this process, see Johnston *et al.* (2000), Norlander *et al.* (2002), and Hinchey *et al.* (2006). Prior to this event, the P-T-t conditions were around 700-800 °C and 9-10 kbar (Norlander *et al.* 2002, Goergen & Whitney 2012). Conditions may have reached 850 °C and 8-12.5 kbar, however, the earlier P-T-t history is largely obscured by subsequent deformation and recrystallization of the rock during the exhumation event (Spalla *et al.* 2011). The end of the main exhumation event during the late Paleocene and early Eocene brought the P-T-t conditions to ~600 °C and 2.5-5 kbar (Norlander *et al.* 2002, Spalla *et al.* 2011, Goergen & Whitney 2012). Findings by Lorencak *et al.* (2001) suggest the Thor-Odin culmination cooled to 250-300 °C by ~45 Ma and exhumation of the area slowed significantly by ~38 Ma. Subsequent cooling and exhumation was variable and a function of movement along regional fault systems (Lorencak *et al.* 2001).

2.3 Magmatic Activity

Anatexis of the Thor-Odin culmination is thought to have been largely triggered by the decompression and exhumation event (Carr 1992, Norlander *et al.* 2002). The resulting partial melt is characterized by abundant migmatites, pegmatites, and plutons in middle crust exposures, particularly in the southern portion of the culmination, where they comprise the Ladybird granite suite (Carr 1992)¹. Geochronological results from the Ladybird granite suite and elsewhere within the culmination indicate that a significant portion of the crust was molten during the decompression and crystallization of the partial melt continued for some time afterwards (Norlander *et al.* 2002, Hinchey *et al.* 2006, Vanderhaeghe *et al.* 1999, Spalla *et al.* 2011, Johnston *et al.* 2000).

The initial formation of granitic bodies was coeval with the development of the most recent metamorphic fabrics during the exhumation event (Vanderhaeghe 1999, Spalla *et al.* 2011). Continuing deformation encouraged further in situ granitic melt formation as well as migration

¹ It is worth noting that many of these bodies were originally thought to be Paleozoic or older because the zircons used for U-Pb geochronology show a distinctly older core surrounded by a significantly younger rim. The young rim was interpreted as overgrowth during Jurassic metamorphic events after the emplacement of the granitic bodies (Okulitch 1985). This thesis follows the interpretation set forth by Carr (1992) that the old cores from zircons are thought to be inherited from the existing crust with the overgrowths forming during the anatectic events of the late Paleocene and early Eocene.

of the melt along weakened planes. It is thought that a residual granitic melt (segregated from the main body of melt with assistance from the deformation) migrated to higher structural levels along a network established by earlier melt at lower structural levels (Vanderhaeghe 1999, Hinchey & Carr 2006). Within the higher structural levels, the melt formed concordant and discordant pegmatite sills and dikes with localized shear zone overprints (Vanderhaeghe 1999, Spalla *et al.* 2011).

Two Jurassic granitic bodies that have been mapped closer to Mount Begbie than the Ladybird granite suite are the Kuskanax batholith and the Galena Bay stock (Kruse *et al.* 2005, Read & Brown 1981, Parrish & Wheeler 1983). Despite their relatively closer proximity to Mount Begbie, it seems unlikely for them to have contributed to the genesis of the pegmatites. The Kuskanax batholith appears to have been metamorphosed soon after its intrusion ~173 Ma and is truncated by the more recent Columbia River Fault (Fig. 2.2). The Galena Bay stock (~150 Ma) intrudes the fault and displays evidence of continuing movement from the fault (Read & Brown 1981, Parrish & Wheeler 1983). If the Kuskanax batholith and Galena Bay stock have contributed to the genesis of the pegmatites, a significant portion of the plutons would have to have remained fluid and to have intruded the Thor-Odin culmination before the formation of the Columbia River Fault.

Figure 2.2: A cross-section through the northern part of the Thor-Odin culmination showing the location of Mount Begbie, the Columbia River Fault, and the general location of the Galena Bay stock, Kuskanax batholith and similar rocks. Figure modified after Kruse (2007).

The pegmatites in this study are not metamorphosed and show only rare foliation; hence, it is improbable that they formed prior to the exhumation and decompression event that started in the late Paleocene. Carr (1992) and Lorencak *et al.* (2001) suggest the Ladybird granite suite wraps around the Monashee complex and extends to the north and west of Mount Begbie. Vanderhaege (1999) and Vanderhaege *et al.* (1999) indicate there may be migmatitic rock similar to the Ladybird granite suite protolith at depth below Mount Begbie. Given the large probable areal extent of the Ladybird granite suite and the potentially migmatitic character of the rock beneath Mount Begbie, it is more likely the pegmatites are related to the Ladybird granite suite than any other known intrusion.

Chapter 3: Pegmatite Occurrences

3.1 Mapping and Sampling

From August 23-29, 2012, pegmatites and related bodies were mapped on a northeastern-facing, relatively gentle and bald slope between the tree line to the north, the toe of Mount Begbie's glacier² to the south, and lateral moraines to the east and west (Fig. 3.1 and Appendix A.1). Due to instability of the weather and time constraints, some pegmatites in the extreme southeastern corner of the study area were not mapped.

Pegmatites were differentiated from migmatites and other veins by the following criteria: it showed relatively pristine primary magmatic features (i.e., little to no foliation) and if it displayed the basic mineral assemblage common to pegmatites in the area (quartz + feldspar +/- tourmaline +/- mica). Unusually large migmatitic pegmatites and veins were also mapped. All were mapped by marking points on a handheld GPS unit at their end points, selected midpoints, bends, and sample sites. The coordinates of the point and relevant comments pertaining to the type of point were noted (Appendix A.3). Photographs of the pegmatite, migmatite, or vein were taken from one of the end points and of any interesting features encountered.

Samples of feldspar were taken from a representative group of pegmatites displaying the basic mineral assemblage; tourmaline and mica samples were also taken if present and removing them from outcrop was possible. Pegmatites were also sampled if the mineralogy indicated fractionation or zoning within the dike. Minerals such as garnet, cordierite, beryl, columbite, apatite and other phosphates were sampled (when possible) in addition to tourmaline, feldspar, and mica from more fractionated pegmatites (Fig. 3.2 and Appendix A.2).

Upon returning from the field, all coordinates were plotted and edited using ArcGIS 10 software. Topography, rivers, lakes, and the glacier were added as a base layer using publicly available topography maps published by the Government of Canada (2012). Regional geology was added and modified after the map compilation of the Thor-Odin culmination by Kruse *et al.* (2005) and Kruse (2006, 2007).

² Note on the glacier: It was an oversight not to map the current extent of the glacier while mapping the pegmatites, as the glacier has retreated considerably (~100 m or more) since the topographic map of the area was made. The topographic map used in this thesis is current for March 26, 2012; it is possible the extent of the glacier has not been updated since the original aerial photos were taken in 1947 and 1951 (Government of Canada 2012, Craig 1966).

Figure 3.1 (preceding page): Map of pegmatites and related bodies within the study area, modified after Kruse *et al.* (2005), Kruse (2006), Kruse (2007), and Government of Canada (2012). **1. BERYL 2. BITOUR 3. CORD 4. CORNER 5. FEED 6. GAR 7. GARMUS 8. GARPPOS 9. GARTOUR 10. GRANITE 11. JAN 12. JUNCT 13. LENS 14. LENS2 15. LI 16. LI2 17. LONG 18. META 19. MUSC 20. ODD 21. PEGMA 22. POCKET 23. QTZ 24. QTZ2 25. QTZ3 26. SCABBY 27. SIMPLE 28. SIMPLE2 29. SIMPLE3 30. SIMPLE4 31. SIMPLE5 32. SIMPLE6 33. SIMPLE7 34. SIMPLE8 35. SIMPLE9 36. SIMPLE10 37. SIMPLE11 38. SIMPLE12 39. SIMPLE13 40. SIMPLE14 41. SIMPLE15 42. SIMPLE16 43. SIMPLE17 44. SKINNY 45. SMALL 46. STUBBY 47. THIN 48. TINY 49. TOUR 50. TOUR2 51. TOURMUS 52. WOBBLE 53. ZONED.** For full legend explanation, see Appendix A.

Mount Begbie Pegmatites

◆ Sample Site

0 50 100 200 300 Meters

Figure 3.2 (preceding page): Map of all sampling sites, modified after Kruse *et al.* (2005), Kruse (2006), Kruse (2007), and Government of Canada (2012). For full explanation of map contents, see Appendix A.

3.2 Descriptions

Individual pegmatite bodies were given names based on prominent minerals or other notable feature (e.g., zoning) observed in the first outcrop encountered. The names of the dikes are not necessarily reflective of its overall nature. Mineral abbreviations used follow Whitney & Evans (2010) unless otherwise specified. Locations of the pegmatites can be found in Appendix A.

3.2.1 The BERYL Pegmatite

This dike is exposed in a cliff immediately below the edge of the tree line (Fig. 3.3a & b). The outcrop is cut by a tiny cobble-filled creek near its eastern end; immediately adjacent to the creek, it is scarred from the repeated visits of numerous mineral collectors. The eastern end is covered by vegetation and the western end is truncated by a large vertical joint with related narrow veinlets extending beyond the joint. The dike has an average width between 4 and 5 meters and was traced for ~43 meters. It has a strike of ~310° and dips to the northeast at ~60°.

The principal mineral assemblage for the dike is quartz + feldspar + biotite. Major accessory phases are beryl (Fig. 3.3c), black tourmaline, muscovite (Fig. 3.3d), garnet (Fig. 3.3e), and apatite. Tourmaline crystals were measured up to 30 cm in length and beryl crystals were measured up to 15 cm long. Minor accessory phases include: monazite, columbite (Fig. 3.3f), cassiterite, xenotime, qitianlingite, altered cordierite, zircon, uranophane, euclase, manganese and iron oxides. Bertrandite, pyrrhotite, uraninite, phurcalite, rutherfordine, and oxylumboroméite are unconfirmed trace accessory minerals in the dike.

The dike has six discernible zones that are highly variable in width; generally the widths of the zones are greater on the hanging wall than on the footwall. The zones consist of: a border zone made up of Qz + Fsp + Bt; a wall zone comprised of the Qz + Fsp + Bt + Tur; an outer intermediate zone with a coarser-grained assemblage of the wall zone; a blocky inner intermediate zone containing of Qz + Ab + Bt + Tur + Ms +/- Brl +/- Kfs; an outer core of nearly pure quartz; and an inner core composed solely of blocky perthite.

Figure 3.3a: The BERYL pegmatite. The southeastern end is seen from slightly beyond the rubble filled creek looking to the southeast. The yellow notebook in the center of the left-hand image is 18 cm tall.

Figure 3.3b: The main length of the BERYL pegmatite as seen from near the northwestern end looking to the southeast.

Figure 3.3c: Beryl crystals from the BERYL pegmatite.

Figure 3.3d: Muscovite book from the BERYL pegmatite.

Figure 3.3e: Thin vein of garnet crystals from the BERYL pegmatite.

Figure 3.3f: Columbite (circled in black) next to tourmaline from the BERYL pegmatite.

3.2.2 The BITOUR Pegmatite

This dike is exposed in a slope beneath a ridge that hosts many pegmatites (Fig. 3.4). It is ~24 m long and widens to nearly 50 cm from a very narrow, pinched eastern end before splitting into two 5 cm wide, parallel dikes that subsequently converge towards the west. Where the two dikes join again, it has a width of ~50 cm before narrowing down into thin veinlets connecting to the PEGMA dike. It has a strike of approximately 295° and has a variable dip towards the southwest. The principal mineral assemblage observed is quartz + feldspar + biotite + tourmaline. The dike did not appear to be zoned and no samples were taken from it.

Figure 3.4: The BITOUR pegmatite as seen from the northwestern end of the pegmatite looking to the southeast.

3.2.3 The CORD Pegmatite

This dike is exposed in the southeastern part of the map area. At its southern end, the dike resembles an alpine vein composed largely of rose quartz and actinolite before transitioning to an aplite dike ~60 cm wide (Fig. 3.5a & b). It attains a width of 2 m before being lost to erosion in places near the midpoint of the dike. In its northern extent beyond the erosional sections, the dike is approximately 1.5 m wide and joins the JUNCT pegmatite. Overall, the dike can be

traced for approximately 55 m and has a strike of $\sim 340^\circ$ with a subvertical dip. The dike only appears to be zoned in the southern end where rose quartz composes the core with an actinolite-feldspar border.

The principal mineral assemblage observed in this body is quartz + feldspar, with major accessory phases of blue and black tourmaline (Fig. 3.5c), muscovite, altered cordierite (Fig. 3.5d), and andalusite (Fig. 3.5e). Minor accessory phases include: beryl, muscovite, chlorite, and iron oxides after cordierite; apatite; zircon; monazite; and xenotime. Nickel oxides are an unconfirmed trace accessory phase.

Figure 3.5a: Overview of the CORD pegmatite, as seen from the southeastern end of the pegmatite looking to the northwest. The backpack near the top of the image is ~ 60 cm long.

Figure 3.5b: A close-up of the alpine vein-like southeastern end of the pegmatite.

Fig. 3.5c: Dark blue tourmaline in the CORD pegmatite.

Figure 3.5d: Altered cordierite crystals in the CORD pegmatite.

Figure 3.5e: Andalusite (pink) in the CORD pegmatite.

3.2.4 The CORNER Pegmatite

This pegmatite is a branch or a feeder for the LONG pegmatite (Fig. 3.6). It is both concordant and discordant with the foliation of the host rock; it is primarily exposed as a concordant sill where sheets of the host rock have spalled off in irregular pieces, giving the pegmatite the appearance of having many corners. It is approximately 20 cm wide and can be

traced for ~20 m. It has a strike of $\sim 315^\circ$, a highly variable dip from subvertical to subhorizontal, and a dip direction from the southwest to the northeast. The principal mineral assemblage observed is quartz + feldspar + tourmaline and it did not display any zoning. No samples were taken from this pegmatite.

Figure 3.6: The CORNER pegmatite (extends towards the upper right corner of the image) where it branches from the LONG pegmatite (pegmatite along the bottom of the image).

3.2.5 The FEED Pegmatite

This dike is exposed on a jagged slope near a narrow gorge and somewhat resembles a migmatite, displaying copious mixing with the host rock (Fig. 3.7). Its central portion has dimensions of $\sim 1.5 \times \sim 4.5$ m while its considerably narrower and branching ends (up to 15 cm wide) curve towards SIMPLE6 to the south and GARMUS to the east for a total extent of ~ 15 m. It has a simple composition, consisting primarily of feldspar + quartz and very minor tourmaline and does not display any zoning. No samples were taken from this pegmatite.

Figure 3.7: The FEED pegmatite as seen from its southeastern end and looking to the north.

3.2.6 The GAR Pegmatite

This dike is a branch from the largest dike, (GRANITE; Fig. 3.1). At the base of the branch, the pegmatite is nearly 12 m wide and encompasses a large xenolith. It narrows to ~3 m before the outcrop is intersected by a minor fault, displacing the continuing dike by ~6 m to the south (Fig. 3.8a). Beyond the fault, the dike narrows down to a few millimeters; the total length of the pegmatite is nearly 105 m. It has a strike of $\sim 310^\circ$ with a subvertical dip.

The dike does not appear to be zoned and has a principal composition of quartz + feldspar + tourmaline. Major accessory minerals are garnet, sekaninaite (Fig. 3.8b), muscovite, biotite, and iron oxides. Minor accessory minerals include beryl, chlorite, and clays after sekaninaite and hübnerite. A possible Ca-analogue of hollandite is an unconfirmed trace accessory phase.

Figure 3.8a: The GAR pegmatite as seen from where it branches from the GRANITE pegmatite. The view is to the northwest. Note the offset of the dike to the south in the upper half of the image.

Figure 3.8b: A large sekaninaite crystal seen in an outcrop of GAR near its split from the GRANITE pegmatite. The chisel head is ~3 cm across.

3.2.7 The GARMUS Pegmatite

This pegmatite is exposed near the center of the study area. It has two long branches to the north and one branch to the south emanating from the middle section of the dike. On average, the dike is ~2 m wide and widens to nearly 6.75 m near its southern terminus before abruptly narrowing to ~50 cm (Fig. 3.9a). The total length of the dike, including its northern branches, is nearly 43 m. It has a strike of ~315° and a subvertical dip.

The dike is principally composed of quartz + feldspar + tourmaline. Major accessory phases of the dike include garnet, muscovite, beryl (Fig. 3.9b), and andalusite. Minor accessory phases of the dike are biotite, apatite, chrysoberyl, columbite, rutile, cassiterite, zircon, and iron oxides. Gahnite and ishikawaite are unconfirmed trace accessory phases. The pegmatite is zoned with quartz + feldspar being the primary assemblage of the border zone. Tourmaline can be found within the intermediate zone whereas garnet, muscovite, beryl, and andalusite occur only within the core.

Figure 3.9a: The GARMUS pegmatite as seen from its southeastern terminus and looking to the northwest.

Figure 3.9b: Beryl (center) and garnet (red) in the GARMUS pegmatite.

3.2.8 The GARPPOS Pegmatite

This dike appears to be a branch from the eastern end of the GRANITE pegmatite but its exact relation to GRANITE was obscured by a large snow field at the time of mapping (Fig. 3.10a & b). The pegmatite is typically 1-2 m wide before narrowing to ~20 cm at its end; it has a length of ~50 m. It has a strike of ~ 310° and is very steeply dipping to the southwest.

The GARPPOS pegmatite has a principal composition of quartz + feldspar + tourmaline (Fig. 3.10c). The major accessory phases are muscovite, garnet, apatite, beryl and triplite (Fig. 3.10d). Minor accessory phases include topaz, triplite-zwieselite, monazite, xenotime, zircon, hübnerite, columbite, rutile, qitianlingite, uraninite, and kaolinite group clays. Autunite is an unconfirmed trace accessory phase. The dike is zoned, with the border being relatively barren and the intermediate and core zones containing the accessory mineral phases.

Figure 3.10a: The GARPPOS pegmatite as seen from its southeastern-most traceable extent, looking to the northwest. The large boulder outcropping from the snow in the upper left of the picture is the GRANITE pegmatite.

Figure 3.10b: The GARPHEOS pegmatite as seen near its midpoint and looking towards where it split from the GRANITE pegmatite under the snow field (Fig. 3.10a).

Figure 3.10c: Green elbaite-rimmed black tourmaline in the GARPPOS pegmatite.

Figure 3.10d: Oxidized, dark gray phosphates (triplite-zwieselite) to the left and right of the base of the large black tourmaline crystal (slightly right of center). A beryl crystal can be seen next to the finger in the GARPPOS pegmatite.

3.2.9 The GARTOUR Pegmatite

This pegmatite has long outcrops between snow patches in the southeastern extent of the study area (Fig. 3.11a). It is typically 60 cm wide and can be traced for approximately 40 m; it has a strike of $\sim 325^\circ$ and is very steeply dipping to the northeast. It has rare, 2 cm pockets that may be an artefact from large, decomposing muscovite crystals. There are numerous, 3 cm diameter patches of quartz-tourmaline intergrowths along the length of the pegmatite.

The principal mineral assemblage of the dike is quartz + feldspar + tourmaline, with major accessory phases of garnet (Fig. 3.11b) and muscovite. Trace accessory phases include beryl and xenotime. The pegmatite is zoned, with the accessory phases occurring only within the core.

Figure 3.11a: The GARTOUR pegmatite as seen from near the mid-point of the pegmatite and looking to the northwest.

Figure 3.11a: Dark red-brown garnets in the GARTOUR pegmatite.

3.2.10 The GRANITE Pegmatite

This dike is exposed as long, beige-colored ridge nearly bisecting the center of the study area and is locally obscured by snowfields and moraine material (Fig. 3.12a & b). It is typically fine-grained, resembling an ordinary granite with rare phenocrysts of feldspar, quartz, and tourmaline. The pegmatite is somewhat foliated in its eastern extent, slightly resembling an orthogneiss in places, but for the most part is not deformed elsewhere. It is offset by ~11 meters to the south by the same minor fault that offset the GAR pegmatite. It has a variable width, ranging from ~20 cm after branching into two parallel dikes in its western extent to ~10 m wide for its middle section. From its eastern extent where it exits a moraine to its western extent to where it enters a snowfield, the dike is approximately 520 m long. It has a strike of ~290° and is very steeply dipping to subvertical to the southwest. Where the dike narrows to the west, the dip is apparently controlled by the foliation of the host rock.

The principal mineral assemblage for this pegmatite is quartz + feldspar + biotite with major accessory phases of muscovite, tourmaline, apatite, and iron oxides. Minor accessory phases include chlorite, monazite, xenotime, rutile, zircon, and calcite. Pyrrhotite and sillimanite are unconfirmed trace accessory minerals. The dike does not display any discernible zoning.

Figure 3.12a: The GRANITE pegmatite as seen from near its mid-point and looking to the southeast. The moraine in the upper left of the background of the image marks the eastern extent of the study area.

Figure 3.12b: The northwestern end of the traceable extent of the GRANITE pegmatite, outcropping as a narrow wall on the left half of the image. The pegmatite on the right side is the MUSC pegmatite.

3.2.11 The JAN Aplites

This pegmatite occurrence is actually two parallel, very thin aplite dikes cross cutting the THIN pegmatite and continuing on in the host metasediments (Fig. 3.13a). They are not more than 3 cm wide, spaced approximately 1 m apart, and extend for at least 10 meters. These dikes have a strike of $\sim 330^\circ$ and have a vertical dip. The aplites are not zoned and the crystals within them are randomly oriented, rather than showing a preferred orientation (Fig. 3.13b). They are principally composed of quartz + feldspar + tourmaline with accessory biotite, garnet, and rutile.

Figure 3.13a: The JAN aplites seen crosscutting the host rock.

Figure 3.13b: A close up view of one of the JAN aplites.

3.2.12 The JUNCT Pegmatite

This pegmatite intersects with the CORD pegmatite near its western end. It has three branches extending from it, with the largest of the branches on its eastern end jutting to the south, not including the CORD pegmatite (Fig. 3.14). The main part of the dike has a strike of $\sim 85^\circ$, a subvertical dip, and is usually no more than 30 cm wide along its 75 m length. The large eastern branch is nearly 5 meters wide from where it splits from the main dike before narrowing down to a few millimeters over a distance of ~ 17 m.

The main assemblage for the dike is quartz + feldspar + tourmaline with biotite, muscovite as major accessory minerals. Apatite, altered cordierite and late chlorite are minor mineral phases for the pegmatite. Zoning was not observed within this dike.

Figure 3.14: The largest eastern branch of the JUNCT pegmatite as seen near its mid-point and looking to the northwest. It joins the JUNCT pegmatite just beyond the crest of the small hill in the center of the image.

3.2.13 The LENS Pegmatite

This pegmatite is exposed to the south of the QTZ veins and has an oblong shape (Fig. 3.15). It has dimensions of approximately $1.5 \text{ m} \times 60 \text{ cm}$, a strike of $\sim 330^\circ$, and has a subvertical dip. The pegmatite is zoned, with grain size increasing from the border to the core; tourmaline crystals in the core can reach 15 cm in length. The principal mineral assemblage is quartz + feldspar + tourmaline.

Figure 3.15: The LENS pegmatite seen from its southeastern end and looking towards the northwest. Beyond it, the mapped quartz veins can be seen QTZ (left), QTZ2 (center), and QTZ3 (right).

3.2.14 The LENS2 Pegmatite

This pegmatite is found within the southeastern part of the study area and greatly resembles a migmatite, due to the number of xenoliths present (Fig. 3.16). It has dimensions of $\sim 2 \text{ m} \times 1 \text{ m}$, a strike of $\sim 325^\circ$, and a subvertical dip. It has pegmatitic and aplitic textures; tourmaline

being more prevalent within the aplite. Tourmaline also replaces some of the xenoliths within the pegmatite. Beyond textural changes between aplite and pegmatite, zoning was not observed in the dike. The principal mineral assemblage for the dike is quartz + feldspar with tourmaline, zircon, and iron oxides as accessory minerals.

Figure 3.16: The LENS2 pegmatite as seen from its northwestern terminus and looking to the southeast.

3.2.15 The LI Pegmatite

This pegmatite is exposed near the center of the study area on top of a small knob (Fig. 3.17a). It has many branches, sprawling in nearly every direction from the knob. The longest branches have a strike of $\sim 310^\circ$ and have a subvertical dip. Branches not on strike have a general extent of 16 m while the branches on strike extend for approximately 38 m. A reaction trail in the host rock can be traced from the longest southeasterly-oriented branch to the northwesterly branch of the LI2 pegmatite. If it is assumed that LI and LI2 are outcrops of the same pegmatite body at depth, the total length of the outcrops along the reaction trail is ~ 200 m.

The principal mineral assemblage for this pegmatite is quartz + feldspar + tourmaline. Major accessory minerals include muscovite, apatite, garnet, lepidolite (Fig. 3.17b), and petalite.

Zircon, qitianlingite, rutile, tantalite, columbite, cassiterite, hübnerite, manganese and iron oxides are minor accessory minerals. Lithiophilite and uraninite are unconfirmed minor accessory minerals. The pegmatite is zoned, with lepidolite, opaque pink tourmaline and minor cleavelandite were observed in the core of the outcrop; black tourmaline and garnet were noted outside of the core. All samples collected from the pegmatite for further analysis came from or near the core.

Figure 3.17a: The LI pegmatite as seen from standing at the bottom of the knob and looking to the south.

Figure 3.17b: Lepidolite in the core of the LI pegmatite on top of the knob.

3.2.16 The LI2 Pegmatite

This pegmatite is exposed near the center of the study area along a very low ridge and along the northeastern and southwestern sides of a large synformal bend in the foliation of the host rock (Fig. 3.18a). Branches of the pegmatite rejoin to the east and west of the synformal feature and split again to the west. Where the branches are joined, the dike is usually not more than 2 m wide; the branches generally do not exceed 1 m in width. It strikes $\sim 320^\circ$ and its dip is primarily subvertical but varies with the foliation of the host rock. Its total length along strike is ~ 105 m. A reaction trail in the host rock can be traced from the northwesterly-oriented branch to the longest southeasterly branch of the LI2 pegmatite. If it is assumed that LI and LI2 are outcrops of the same pegmatite body at depth, the total length of the outcrops along the reaction trail is ~ 200 m.

The principal mineral assemblage for this dike is quartz + feldspar + tourmaline with accessory minerals of muscovite, biotite, lepidolite, garnet, apatite, triplite-zwieselite (Fig. 3.18b), columbite, rutile, zircon, and manganese and iron oxides. Unconfirmed accessory minerals include lithiophilite, lipscombite, hureaulite, amblygonite, xenotime, and clays.

The pegmatite has four distinct zones: a narrow border zone with the assemblage Qt + Fsp + Tur ;a wall zone with Qt + Fsp + Bt +Tur +/- Brl; an intermediate zone of Qt + Fsp + Ms + black Tur + green Tur + Grt + phosphates; and a core with Qt + Fsp + Ms + Bt + Lpd + blue Tur + green Tur + pink Tur + black Tur +/- Brl +/- Grt (Fig. 3.18c).

Figure 3.18a: The LI2 pegmatite as seen from near its southeastern end and looking to the northwest.

Figure 3.18b: Dark gray oxidized phosphates (triplite-zwieselite) in the LI2 pegmatite.

Figure 3.18c: The core of the LI2 pegmatite showing pink lepidolite and pale green tourmaline.

3.2.17 The LONG Pegmatite

This dike is located in the western half of the study area (Fig. 3.19) and connects with the CORNER pegmatite. The southeastern end of the dike is ~1 m wide. For most of the northwestern end of the dike, it is split into two parallel branches before rejoining near the end of the traceable outcrop. One branch primarily remains concealed by the host metasediment and is only revealed occasionally in more eroded areas. The other branch is typically more visible and can be nearly 1.5 m wide. The dike can be traced for nearly 220 m, has a strike of 290° and a subvertical dip that is occasionally variable depending on the foliation of the host rock.

The principal mineral assemblage of this pegmatite is quartz + feldspar + tourmaline with major accessory minerals of garnet, rutile, iron oxides and sulfides. Trace accessory minerals include allanite and galena. The dike is subtly zoned with garnet and larger crystals of tourmaline in its core.

Figure 3.19: The LONG pegmatite as seen from near its southeastern end and looking towards the northwest.

3.2.18 The META Migmatitic Pegmatite

This is the only migmatitic pegmatite mapped in the study area and it is exposed along a ridge near the LONG and PEGMA pegmatites. It varies from a few centimeters to nearly 1 m wide along its length. It is typically at least 50 cm wide and can be traced for nearly 125 m, making it larger than most other migmatitic leucosome layers in the area, which are generally much shorter and thinner. It has a strike of approximately 300° and its dip is always concordant with the foliation, which is primarily shallowly dipping to nearly 45° towards the southwest (Fig. 3.20). It is composed of quartz + feldspar with very rare biotite, muscovite, and tourmaline. No samples were taken from this granitic body.

Figure 3.20: The META migmatitic pegmatite as seen near its thickest section near its mid-point and looking towards the northwest.

3.2.19 The MUSC Pegmatite

This pegmatite is subparallel to the GRANITE pegmatite and is located slightly to the south of the northwestern extent of GRANITE. The outcrop is partially obscured by cobbles and plant matter near its eastern end (Fig. 3.21). It is nearly 1 m wide and can be traced for nearly 54 m. It has a strike of $\sim 290^\circ$ and is steeply dipping to the southwest to subvertical. Its primary mineral assemblage is quartz + feldspar + muscovite with accessory tourmaline and biotite. It is zoned with a small quartz core.

Figure 3.21: The MUSC pegmatite as seen from its southeastern end and looking towards the northwest. GRANITE outcrops in the right side of the image.

3.2.20 The ODD Pegmatite

This pegmatite is exposed in a short cliff topping a talus pile near the SIMPLE10 pegmatite in the northern part of the study area (Fig. 3.22). It was not very well documented due to the precarious footing. Its length is uncertain but it appeared to be ~2 m wide with a strike of ~300° and to be very steeply dipping to the southwest. It did not display any discernible zoning and had a primary mineral assemblage of quartz + feldspar with accessory tourmaline. This dike is odd with respect to the others within the study area because it had only had trace (rather than abundant) accessory tourmaline, the feldspar crystals seemed to be distorted, and it appeared to have slickensides. No samples were taken from this pegmatite.

Figure 3.22: The ODD pegmatite as seen from slightly to the northwest of it and looking towards the southeast.

3.2.21 The PEGMA Pegmatite

This pegmatite outcrops slightly to the south of the BITOUR pegmatite. In its southeastern and northwestern extent, it is exposed as a single pegmatite while in its middle section towards the southeast, it splits into two main branches around the northeast and southwest edges of a synformal feature in the foliation of the host rock (Fig. 3.23). To the immediate northwest of the synformal feature and before it continues to the northwest as a single dike, it splits in to a myriad of branches, some of which extend towards the end branches of the BITOUR pegmatite. It has a changing character, resembling a hybrid between a migmatite and a pegmatite to the southeast and around the synformal feature; appearing as a much more pegmatite-like body at the northwestern end of the synformal feature where it splits into numerous branches; and looking undeniably like a pegmatite at the end of its traceable northwestern extent.

The dike is of variable width but is typically less than 1 m wide and can be traced for ~55 m. It has a strike of ~310° and its dip seems to be somewhat controlled by the foliation of the host rock, ranging from subvertical to shallowly dipping to the southwest.

The principal mineral assemblage for this pegmatite is quartz + feldspar + biotite + tourmaline with accessory muscovite, zircon, apatite, xenotime, and clay minerals. It is zoned, with the assemblage Qt + Fsp + Bt + Tur in a finer grained border zone and Qt + Fsp + Tur in a much blockier, coarser-grained core. Tourmaline crystals in the core can reach to 10 cm in length. Samples for this pegmatite were gathered where it started to resemble a more pegmatite-like body and in its pegmatitic northwestern end.

Figure 3.23: The PEGMA pegmatite as seen from a point where its two main branches join and looking to the southeast.

3.2.22 The POCKET Pegmatite

This pegmatite is exposed south of the QTZ veins and to the west of LENS on a small ridge (Fig. 3.24a). It has a series of small, elongated quartz-filled miarolitic cavities in its core (Fig. 3.24b). The outcrop is short and wide, with dimensions of $\sim 4 \text{ m} \times 1.5 \text{ m}$ for its middle and narrowing to 15 cm at its ends. The dike has a strike of $\sim 345^\circ$ and a subvertical dip.

Its principal mineral assemblage is quartz + feldspar + biotite + tourmaline with accessory apatite, and unconfirmed iron oxides. It has several large crystals in its core that are completely altered to fine-grained micas. Given the largely intact shape of the large crystals, they may have once been apatite or cordierite.

The pegmatite is zoned with the assemblage Qt + Fsp + Bt + Tur in its border zone. The assemblage is much the same for its wall and intermediate zones being only slightly coarser grained. The core is very blocky and is composed largely of feldspar and the altered mineral and containing long and narrow, quartz-filled miarolitic cavities.

Figure 3.24a: The POCKET pegmatite as seen from its southeastern terminus looking towards the northwest.

Figure 3.24b: The largest miarolitic cavity in the POCKET pegmatite. The pencil is ~15 cm long.

3.2.23 The QTZ Vein

This quartz vein is exposed on the top of a ridge slightly to the north of the LENS and POCKET pegmatites (Fig. 3.25). This vein is the western-most in a series of curving, subparallel quartz veins, including QTZ2 and QTZ3 (Fig. 3.15). It is nearly 1 m wide in its middle before slowly tapering to ~2 cm thick at its ends. The vein is ~29 m long, has a strike of ~330° along its straightest section, and has a subvertical dip. It is composed almost entirely of quartz and contains rare feldspar crystals where it is widest. Its northwestern-most end almost appears to be aplitic. No samples were taken from this vein.

Figure 3.25: The QTZ vein as seen from between its southeastern end point and its mid-point and looking towards the northwest.

3.2.24 The QTZ2 Vein

This vein is the center vein of a series of curving, subparallel quartz veins which include QTZ and QTZ3 (Fig. 3.15 & Fig. 3.26). It outcrops on the top of a ridge, slightly to the north of the LENS and POCKET pegmatites. It is ~60 cm wide in its middle and slowly tapers to a few centimeters wide at its ends. It extends for approximately 22 m, has a strike of $\sim 310^\circ$, and a subvertical dip. It is composed entirely of quartz; where the vein is widest, it has a rosy hue. No samples were taken from this vein.

Figure 3.26: The QTZ2 vein as seen from near its southeastern end and looking towards the northwest.

3.2.25 The QTZ3 Vein

This vein is the eastern most of series of curving, subparallel quartz veins which also includes QTZ and QTZ2 (Fig. 3.15 & Fig. 3.27a). It is exposed within the short cliff face of a ridge as well as outcropping on top of the ridge. Unlike the other veins, it appears to have a relatively complex relationship with nearby aplites, either intersecting with them or perhaps being related to them. In its center on top of the ridge, the vein is nearly 90 cm wide and takes on an aplite-like texture. To the southeast from this point, the vein slowly tapers down to only a few centimeters wide. To the northwest from the center point, the quartz-rich aplite-like vein can be traced over the ridge and along the cliff face. Along the cliff face, it bears much greater resemblance to an aplite than a quartz vein (Fig. 3.27b). The aplite can be traced along the cliff face to the east and the west; it nearly intersects the QTZ vein in the west.

The vein and associated aplites can be traced for ~55 m. Its strike along the ridge top where it is straightest is $\sim 310^\circ$ and has a subvertical dip. Along the cliff face, the vein has strike of $\sim 80^\circ$. Its dip along the cliff face was not discerned. The vein is primarily composed of quartz which takes on a rosy hue where the vein is widest. The aplitic portions have the composition of quartz + feldspar + biotite; some of the biotite is altering to chlorite. No samples were taken from this vein.

Figure 3.27a: The QTZ3 vein as seen near its southeastern end and looking towards the northwest.

Figure 3.27b: The intersection between a quartz vein (top of the image; oriented vertically) and an aplite (bottom of the image; oriented horizontally) in the QTZ3 vein.

3.2.26 The SCABBY Pegmatite

This pegmatite is exposed near the northwestern end of the LONG pegmatite (Fig. 3.28). When viewed from standing high on the slope above it, the pegmatite appears to be of substantial size. Upon closer inspection, the dike is mostly eroded away. It is nearly 6 cm thick in patches near its northwestern extent. It can be traced for ~143 m along a strike of $\sim 295^\circ$. Its dip is nearly always perpendicular to the foliation of the host rock and ranges from subhorizontal to moderately dipping to the southwest. No samples were taken from this pegmatite.

Figure 3.28: The SCABBY pegmatite as seen from its southeastern end and looking to the northwest.

3.2.27 The SIMPLE Pegmatite

This pegmatite outcrops to the east of the LI2 pegmatite and to the immediate west of a small creek. It intersects with the STUBBY pegmatite near its southeastern terminus (Fig. 3.29). It is coarser grained in its ends but has a primarily aplitic middle section. The pegmatite reaches nearly 2 m wide and can be traced for ~64 m. Its northwestern end tapers considerably and spreads into numerous smaller veins while its southwestern end is hidden in the creek, 5-10 meters to the southeast from its intersection with STUBBY. SIMPLE has a strike of $\sim 355^\circ$ and a subvertical to vertical dip.

Other than textural changes near its ends, the dike did not display any obvious zoning. Its principal mineral assemblage is quartz + feldspar + tourmaline + muscovite + biotite and it has trace monazite. Two tourmaline samples were taken, one from the aplite and one from a tiny pegmatitic vein in the aplite.

Figure 3.29: The SIMPLE pegmatite as seen from its southeastern end and looking to the northwest. The STUBBY pegmatite is in the foreground with the notebook on top of it.

3.2.28 The SIMPLE2 Pegmatite

This is a small pegmatite exposed on a ridge (Fig. 3.30) and is located between the SIMPLE and SIMPLE3 pegmatites. Like the SIMPLE dike, its ends are coarser grained than its more aplitic middle. The aplite section in its middle is ~1 m thick. It can be trace for ~5 m, with a strike of ~65° and ~40° dip to the southeast. Its principal mineral assemblage is quartz + feldspar + biotite with trace, fine grained tourmaline. Some of the biotite is altered to chlorite. No zoning was observed in this pegmatite.

Figure 3.30: The SIMPLE2 pegmatite as seen from the south and looking to the north.

3.2.29 The SIMPLE3 Pegmatite

This pegmatite is exposed on top of a small ridge between the SIMPLE2 and SIMPLE4 pegmatites (Fig. 3.31). It is a narrow dike, not more than 20 cm wide and can be traced for ~11 m. It has a strike of $\sim 340^\circ$ and a shallow dip of $\sim 15^\circ$ to the northeast—always subparallel to the foliation of the host rock. It has a principal mineral assemblage of quartz + feldspar + tourmaline. No zoning was observed in this dike.

Figure 3.31: The SIMPLE3 pegmatite as seen from the south and looking to the north.

3.2.30 The SIMPLE4 Pegmatite

This pegmatite is exposed on a ridge between the SIMPLE3 and SIMPLE5 pegmatites (Fig. 3.32). It grades from pegmatitic texture at its southeastern end to aplitic in texture at its northwestern end. Its width varies from 20 cm to nearly 1 m and can be traced for nearly 22 m. It has a strike of $\sim 330^\circ$ and is very steeply dipping to the southeast. It has a principal mineral assemblage of quartz + feldspar + tourmaline. Other than textural changes, no zoning was observed in this dike.

Figure 3.32: The SIMPLE4 pegmatite as seen from near its southeastern end and looking to the northwest.

3.2.31 The SIMPLE5 Pegmatite

This pegmatite is exposed on a ridge and is located to the east of the SIMPLE4 pegmatite. It has two distinct parts: a section that is nearly 7 m wide incorporating much of the host rock with a strike of $\sim 320^\circ$ (Fig. 3.33a) and a section that has a width that is typically 20 cm but can be up to 50 cm wide, striking $\sim 275^\circ$ (Fig. 3.33b). Both sections have a subvertical dip and its total length is ~ 70 m. The texture for the dike is aplitic with a few porphyritic feldspar crystals. Its principal mineral assemblage is quartz + feldspar + tourmaline with unconfirmed trace tantalite.

Figure 3.33a: The SIMPLE5 pegmatite where it strikes $\sim 320^\circ$. The view is to the northwest.

Figure 3.33b: The SIMPLE5 pegmatite where it strikes $\sim 275^\circ$. The view is to the west.

3.2.32 The SIMPLE6 Pegmatite

This pegmatite is exposed on a steep slope near the center of the study area. Its southeastern end is exposed at the top of the slope near the FEED pegmatite (Fig. 3.34a) and can be traced for ~94 m to its northwestern end near the LI pegmatite at the bottom of the slope (Fig. 3.34b). It has three, short branches that extend to the southeast from the main body of the pegmatite. It is typically about 40 cm wide, except where the branches join the main pegmatite. In those places, the width tends to be ~1 m wide. The short branches are up to 3 m wide and tend to incorporate many xenoliths. In general, it has a strike of $\sim 335^\circ$ and a subvertical dip. The principal mineral assemblage for the dike is quartz + feldspar with accessory tourmaline. The dike is slightly zoned texturally with blocky feldspar and quartz where the branches join the main dike.

Figure 3.34a: The SIMPLE6 pegmatite as seen from the end of one of its southeastern branches at the top of the slope.

Figure 3.34b: The SIMPLE6 pegmatite as seen from the southeastern end of the branch at the bottom of the slope.

3.2.33 The SIMPLE7 Pegmatite

This pegmatite is exposed on a ridge between the SIMPLE6 pegmatite and the SIMPLE9 pegmatite (Fig. 3.35a). The pegmatite is roughly 30 cm wide and ~11 m long with a strike of approximately 350° and subvertical dip. It terminates rather abruptly on its northern end due to erosion (Fig. 3.35b). The principal mineral assemblage composing this pegmatite is quartz + feldspar + biotite with accessory tourmaline. No zoning was observed in this pegmatite.

Figure 3.35a: The southern end of the SIMPLE7 pegmatite at the ridge top looking to the north.

Figure 3.35b: The northern end of the SIMPLE7 pegmatite underneath the ridge, looking to the south.

3.2.34 The SIMPLE8 Pegmatite

This pegmatite is exposed in the southeastern part of the study area slightly to the south of the CORD pegmatite. It is nearly 75 cm wide in its center and tapers to a few centimeters wide at its end (Fig. 3.36). The dike is ~11 m long with a strike of approximately 275° and a subvertical dip. It has a basic mineral assemblage of quartz + feldspar with minor tourmaline. Zoning was not observed and no samples were taken.

Figure 3.36: The SIMPLE8 pegmatite as seen from its eastern end and looking to the west.

3.2.35 The SIMPLE9 Pegmatite

This pegmatite outcrops near the center of the study area and can be traced to the northwest for ~252 meters before being covered by the lateral moraine marking the western boundary of the study area. The outcrop is not entirely continuous along its length, being occasionally interrupted by snowfields and erosion. The dike is variable in width, generally between 50 cm and 1 m wide; it reaches nearly 7.5 m wide where it outcrops in the southeast (Fig. 3.37a). The dike has one branch near its southeastern end that can be traced along a low cliff (Fig. 3.37b).

The overall strike of the dike is $\sim 315^\circ$ and it generally has a subvertical dip; away from the main outcrop in the southeast, the pegmatite appears to be very steeply dipping to the northeast.

Its principal mineral assemblage is quartz + feldspar + tourmaline with major accessory minerals of biotite, muscovite, partially altered cordierite (Fig. 3.37c), beryl (Fig. 3.37d), and garnet. Minor accessory mineral phases include muscovite; biotite; chlorite after biotite; muscovite, beryl, smectite group and kaolinite group clays, and iron oxides as alteration products from cordierite; bertrandite as an alteration product in primary beryl; monazite; xenotime; and zircon. Rutile is an unconfirmed accessory mineral.

The dike is subtly zoned; the core of the dike is blocky and contains all mineral types while the border zone primarily consists of feldspars, quartz, and tourmaline with trace monazite, xenotime, and zircon. The pegmatite also has patchy occurrences of aplite primarily composed of feldspars and quartz with minor biotite, tourmaline, and trace garnet.

Figure 3.37a: The main body of the SIMPLE9 pegmatite as seen from its southeastern end and looking towards the northwest.

Figure 3.37b: The northwestern end of the SIMPLE9 branch. The length of one of the black gloves piled near the center of the image is ~22 cm.

Figure 3.37c: Partially altered cordierite (dark green) with black tourmaline and muscovite-quartz intergrowths in the SIMPLE9 pegmatite.

Figure 3.37d: Beryl (light blue, in center of the garnet), garnet, and black tourmaline in the SIMPLE9 pegmatite.

3.2.36 The SIMPLE10 Pegmatite

This pegmatite is exposed in a low ridge in the northern part of the study area near the ODD pegmatite (Fig. 3.38). It has a variable width between 50 cm and 1 m and can be traced for ~25 m. It has a strike of approximately 300° and is very steeply dipping to the southwest to subvertical. The dike has a principal mineral assemblage of quartz + feldspar with accessory tourmaline. No zoning was observed in this pegmatite and no samples were taken.

Figure 3.38: The SIMPLE10 pegmatite as seen from its southeastern end and looking to the northwest.

3.2.37 The SIMPLE11 Pegmatite

This pegmatite is a branch of the GRANITE pegmatite exposed slightly to the south of GRANITE (Fig. 3.39). It extends to the southeast from where it joins GRANITE for ~16 m before being covered by a snowfield. It has a width of ~50 cm at its widest, a strike of approximately 259°, and a very steeply dipping to the southwest to subvertical dip. It has a principle mineral assemblage of quartz + feldspar with accessory tourmaline and biotite along with trace iron oxides and sulfides. No zoning was observed in this pegmatite.

Figure 3.39: The SIMPLE11 pegmatite as seen from near its southeastern end and looking along its length to just before it joins with the GRANITE pegmatite.

3.2.38 The SIMPLE12 Pegmatite

This is the northernmost pegmatite in a series of three pegmatites (SIMPLE12, ZONED, and SIMPLE13) exposed on a slope in the western part of the study area. The dike has two branches at its northwestern end and where the branches join, it is spotted with rusty stains. It can be traced for nearly 155 m to where it enters a snowfield at its northwestern extent. Snow also obscures a portion of the dike near its middle. At its widest, the pegmatite is ~1.5 m; its

ends narrow to only a few centimeters across (Fig. 3.40). It has a strike of approximately 305° and a subvertical dip.

The principal mineral assemblage of the dike is quartz + feldspar with accessory tourmaline, biotite, and iron oxides. The presence of zircons and muscovite in the dike is unconfirmed. The dike is subtly zoned in its pegmatitic sections, with rare tourmaline fans in the core of the dike. Aplitic sections of the dike do not appear to be zoned and bear resemblance to the GRANITE pegmatite.

Figure 3.40: The SIMPLE12 pegmatite as seen from its southeastern end and looking to the northwest.

3.2.39 The SIMPLE13 Pegmatite

This is the southernmost pegmatite in a series of three pegmatites (SIMPLE12, ZONED, and SIMPLE13) exposed on a slope in the western part of the study area (Fig. 3.41). It can be traced for nearly 81 m; the outcrop is obscured by vegetation and erosion along its middle section. The pegmatite is approximately 60 cm wide and narrows to a few centimeters at its ends. Its strike is $\sim 300^\circ$ with a subvertical dip. Its principal mineral assemblage is quartz + feldspar with accessory tourmaline and iron oxides. Zoning was not observed in this pegmatite.

Figure 3.41: The SIMPLE13 pegmatite as seen from its southeastern end and looking towards the west.

3.2.40 The SIMPLE14 Pegmatite

This pegmatite outcrops along the edge of a ridge near a tall cairn (Fig. 3.42) and slightly to the north of the proglacial pond. The outcrop is frequently interrupted by erosion but could be traced for ~26 m. A recrystallization trail in the host rock could be traced for a long distance beyond the western terminus of the dike. The eastern end of the pegmatite is split into two short branches; each branch is ~1 m wide while the main body of the dike is ~2 m wide. Its overall strike is ~290° with a subvertical dip. The principal mineral assemblage for the dike is quartz + feldspar with accessory tourmaline, biotite, and garnet. No zoning was observed in the dike.

Figure 3.42: The SIMPLE14 pegmatite as seen from its eastern end and looking towards the west.

3.2.41 The SIMPLE15 Pegmatite

This pegmatite is exposed for a short distance between large rocks in a boulder field north of the glacier. Only a 1.5 m long section of the 50 cm wide dike was visible (Fig. 3.43). It has a strike of $\sim 310^\circ$; the dip could not be ascertained from the outcrop but is presumed to be subvertical or vertical. Its principal mineral assemblage is quartz + feldspar with accessory tourmaline; feldspar was the only mineral sampled from the dike. Zoning was not observed in the pegmatite.

Figure 3.43: The visible extent of the SIMPLE15 outcrop.

3.2.42 The SIMPLE16 Pegmatite

This pegmatite outcrops in a boulder field in the southern part of the study area. It is frequently hidden by boulders but could be traced for approximately 41 meters. It appears to branch multiple times underneath the boulders with each branch being approximately 30 cm wide. It has an overall strike of $\sim 90^\circ$ and is very steeply dipping the south to subvertical (Fig. 3.44). It has a principal composition of quartz + feldspar + tourmaline with accessory muscovite, biotite, chlorite, and rutile. Columbite and zircon are unconfirmed accessory minerals. Zoning was not observed in the pegmatite.

Figure 3.44: The eastern end of the SIMPLE16 pegmatite; the view is to the west.

3.2.43 The SIMPLE17 Pegmatite

This pegmatite outcrops on either side of a small, rubble filled creek. It can be traced for ~ 14 m, if the ~ 7 m interruption caused by the stream is included (Fig. 3.45). It has a maximum width of ~ 50 cm and narrows to ~ 5 - 10 cm at its ends. It has a strike of approximately 320° and a subvertical dip. It has a principal composition of quartz + feldspar + tourmaline, with the tourmaline crystals reaching 10 cm long and 2-3 cm wide. Zoning was not observed in this pegmatite.

Figure 3.45: The SIMPLE17 pegmatite as seen from near its northwestern end and looking to the southeast. The pegmatite is oriented diagonally in the image from the lower left corner to the upper right corner.

3.2.44 The SKINNY Pegmatite

This pegmatite outcrops near a ridge near small, likely seasonal, waterfall. It is approximately 13 m long, with a width of ~10 cm, tapering to a few centimeters at its ends. It has a strike of ~345° and vertical dip (Fig. 3.46). The dike is subtly zoned, with narrow, fine-grained border zones and a coarser grained core. Its principal mineral assemblage is quartz + feldspar + tourmaline with rare grains of feldspar being blue-gray perthite. The dike has accessory garnet, muscovite, biotite, rutile, and unconfirmed accessory zircon.

Figure 3.46: The SKINNY pegmatite as seen from near its southeastern end and looking to the northwest.

3.2.45 The SMALL Pegmatite

This dike is exposed slightly to the north of the southeastern end of the GRANITE pegmatite. The outcrop is interrupted by a creek covered in plant life and large boulders near its southeastern extent (Fig. 3.47). It can be traced for ~30 meters and typically has a width of about 1 m. The pegmatite has a strike of approximately 315° and is steeply dipping to the southwest. It has a principal mineral assemblage of quartz + feldspar + tourmaline with accessory biotite, muscovite, and garnet. Beryl, columbite, zircon, andalusite, and xenotime are unconfirmed accessory minerals. The dike displays an unusual zoning pattern for this field of pegmatites—muscovite is prevalent in its southeastern end while biotite is much more common

in its northwestern extent. Where muscovite is prevalent, some of it is hosted as muscovite-quartz intergrowths in the core.

Figure 3.47: The SMALL pegmatite as seen from near its southeastern end looking towards the west. The portion of the dike near the top center of the photograph has muscovite-quartz intergrowths in its core.

3.2.46 The STUBBY Pegmatite

This pegmatite intersects the southeastern end of the SIMPLE pegmatite (Fig. 3.29). The dike is ~1 m wide and extends for 10 m on a strike of 65° with a subvertical dip. It has a composition of quartz + feldspar + tourmaline. No zoning was observed in the dike and no samples were taken from it.

3.2.47 The THIN Pegmatite

This pegmatite is exposed in the western part of the study area and is crosscut by the JAN aplites. Despite the outcrop being frequently subject to erosion and covered by snow, it can be traced for nearly 63 m (Fig. 3.48). It has a typical width of ~20 cm, a strike of approximately

300°, and a subvertical dip. The dike has the assemblage of quartz + feldspar + tourmaline and is zoned with a quartz core visible in its middle section.

Figure 3.48: The THIN pegmatite as seen near its southeastern end and looking towards the northwest.

3.2.48 The TINY Pegmatite

This pegmatite is a short branch from the GRANITE pegmatite near the larger branch TOURMUS (Fig. 3.49). The dike is not more than 20 cm wide and extends for approximately 3 m. It has a strike of ~310° and is very steeply dipping to the southwest. The pegmatite is composed of quartz + feldspar + tourmaline + slightly chloritized biotite. It is subtly zoned with narrow, fine-grained border zones and a coarser grained core. No samples were taken from this dike.

Figure 3.49: The TINY pegmatite (foreground) as seen from near its northwestern end and looking towards where it joins the GRANITE pegmatite to the south (background).

3.2.49 The TOUR Pegmatite

This pegmatite outcrops in the southeastern part of the study area to the east of the GARTOUR pegmatite. It can be traced ~18 m between its very narrow southeastern end and 40 cm wide erosional northwestern end; along the middle section, it has a width of ~3 m (Fig. 3.50a). It has a strike of approximately 325° and a subvertical dip. The principal mineral assemblage is quartz + feldspar + tourmaline with accessory muscovite, apatite, altered cordierite, and iron oxides. Zircon is an unconfirmed accessory mineral. The pegmatite is zoned, with a very blocky core with quartz-cordierite intergrowths (Figure 3.50b) and muscovite fans. The border zone is finer grained and noticeably lacks cordierite.

Figure 3.50a: The TOUR pegmatite as seen from its northwestern end and looking towards the southeast.

Figure 3.50b: Cordierite-quartz intergrowth in the TOUR pegmatite.

3.2.50 The TOUR2 Pegmatite

This pegmatite outcrops mid-way between the GARTOUR and JUNCT pegmatites. The dike is filled with xenoliths and is ~3 wide and nearly 5 m long (Fig. 3.51). It has a strike of approximately 325° ; the dike is presumed to be subvertical but could not be discerned from the outcrop. It has a composition of quartz + feldspar + tourmaline. Zoning was not observed in the dike and no samples were taken.

Figure 3.51: The TOUR2 pegmatite as seen from near its southeastern end and looking towards the northwest.

3.2.51 The TOURMUS Pegmatite

This pegmatite branches off from the GRANITE pegmatite near the TINY pegmatite in the eastern part of the study area. Where it splits from the GRANITE dike, it is made up of a series of thin dikes and veinlets no more than 20 cm wide but covers an area of ~3 m (Fig. 3.52a). The

main body of the dike is usually not more than 1 m wide and extends for ~38 m. It has a strike of approximately 310 m and a subvertical dip.

The dike has a principal assemblage of quartz + feldspar + tourmaline with accessory muscovite, biotite, garnet, apatite, beryl (Fig. 3.52b), triplite-zwieselite, and zircon. The dike is zoned similarly to the SMALL pegmatite with muscovite in its southeastern end and biotite as the principal mica in its northwestern end. Where muscovite is prevalent, some of it is hosted as muscovite-quartz intergrowths in the core. The border zone is finer grained and noticeably lacks beryl and triplite-zwieselite.

Figure 3.52a: The TOURMUS pegmatite as seen from where it branches from the GRANITE pegmatite and looking towards the northwest. The three pegmatites in the background from left to right are GARMUS, LI2, and SIMPLE.

Figure 3.52b: A white beryl crystal (centered between the fingers) in the TOURMUS pegmatite.

3.2.52 The WOBBLE Pegmatite

This pegmatite is exposed in the southeastern part of the study area to the west of the CORD pegmatite. It has a meandering character and is composed of many small dikelets (Fig. 3.53a). At its widest, the main body of the dike is ~30 cm wide. Overall, the dike can be traced for nearly 20 m, has a strike of ~320 m. Its dip was not ascertained from the outcrop but it is assumed to be subvertical. It has a principal mineral assemblage of quartz + feldspar + tourmaline with accessory garnet. It has a blocky core with fine grained tourmaline-quartz intergrowths (Fig. 3.53b).

Figure 3.53a: A representative section of the WOBBLE pegmatite with its blocky core near the yellow notebook and meandering veinlets on the left half of the image.

Figure 3.53b: Tourmaline-quartz intergrowths in the core of WOBBLE.

3.2.53 The ZONED Pegmatite

This is the central pegmatite in a series of three pegmatites (SIMPLE12, ZONED, and SIMPLE13) exposed on a slope in the western part of the study area (Fig. 3.54a). It can be traced for approximately 95 m, has a strike of $\sim 305^\circ$, and a 45° to subvertical dip to the south. This pegmatite is easily distinguished from other pegmatites in the study area by its large quartz core that occasionally has a rosy hue (Fig. 3.54b). At its widest, the quartz core ~ 60 cm wide flanked by border zones of 15 to 20 cm wide. The quartz core hosts rare feldspar crystals that reach nearly 30 cm in length. The principal mineral assemblage for this pegmatite is quartz + feldspar with accessory tourmaline and biotite.

Figure 3.54a: The ZONED pegmatite as seen from its southeastern end and looking to the west.

Figure 3.54b: Rose quartz in the core of the ZONED pegmatite.

3.2.54 Other Pegmatite Bodies

Additional pegmatites in the area were noted and photographed but were not mapped due to time and weather constraints (Fig. 3.55a & b). At a glance, they are compositionally similar to other pegmatites in the study area, primarily containing coarse-grained tourmaline crystals in a matrix of quartz and feldspar. Future work should include mapping and sampling these pegmatites.

Figure 3.55a: Unmapped pegmatites. The left image is of the XENO pegmatite; the right image is of the MORE pegmatites—three MORE dikes are visible in this image.

Figure 3.55b: A cordierite-quartz intergrowth in an unmapped pegmatite.

3.3 Summary

In general, the pegmatites in the study area are long and narrow bodies, with most having dimensions less than one meter wide with a length of at least 10 m. Twenty of the bodies mapped exceed 50 m in length, whereas seven pegmatites were less than 10 m in length. Nearly all strike between 295° and 330° with a subvertical dip. These orientations appear to be controlled by exhumation-related shear zones that were previously mapped by other workers.

The most basic mineral assemblages observed in the pegmatites are quartz + feldspar + black tourmaline or quartz + feldspar + biotite (e.g., SIMPLE2, SIMPLE3, and SIMPLE4). Intermediate assemblages add muscovite, garnet, beryl, cordierite, and oxides to the basic assemblage (e.g., BERYL, TOUR, and CORD). Highly fractionated assemblages (e.g. GARPPOS, LI, and LI2) contain all of these features as well as phosphates other than apatite, monazite, and xenotime; lepidolite; and multi-colored tourmaline.

Many pegmatites exhibit subtle zoning with blockier cores than fine-grained border zones. Intermediate and core zones usually display increasing fractionation. Where quartz is a major component of the core of the dike, some of the quartz may be the variety rose quartz.

Chapter 4: Whole-Rock Geochemistry

Nine hand samples were taken at intervals from the central part of the fine-grained, primitive GRANITE pegmatite (Fig. 4.1). The reason for collecting samples from the GRANITE pegmatite is two-fold: (1) analyses for major and trace elements allow for the assessment of the fractionation of the dike and (2) since the dike stretches through a significant portion of the study area (Fig. 3.1 & Appendix A), the analyses provide a baseline fractionation trend for all of the pegmatites. The selected samples were largely free from signs of weathering and despite their small size (each weighing less than one kilogram), were reasonably representative of the GRANITE pegmatite at the sample location. Bulk sampling from the pegmatite was not feasible due to weight restrictions. The whole-rock geochemistry results can be seen in Table 4.1 and Table 4.2.

In Figure 4.2, the Zr/Hf, Nb/Ta, Na/K, and Rb/Sr ratios were plotted against the sample locality to assess overall fractionation trends. Decreases in the Zr/Hf, Nb/Ta, and Na/K ratios indicate increasing fractionation, whereas increasing Rb/Sr ratios indicate increasing fractionation in peraluminous granites and pegmatites (London 2008). The Zr/Hf ratio shows a marked decrease from the southeast to northwest sample sites in the GRANITE pegmatite, whereas the decrease in the Nb/Ta and Na/K ratios is more subtle. The Rb/Sr shows a dramatic increase along the southeast to the northwest end of the pegmatite. The results show that the overall fractionation of the pegmatite increases somewhat towards the northwest.

Similar trends suggesting increasing fractionation can be observed in Figure 4.3, although the results are much more variable. Concentrations of Li, Be, Cs, and Pb can be expected to increase with increasing fractionation for S-type granites (London 2008, Finger & Schiller 2012). Likewise, the aluminum saturation index (ASI; $ASI = \text{mol Al}_2\text{O}_3 / (\text{Na}_2\text{O} + \text{K}_2\text{O} + \text{CaO} - 1.67 \times \text{P}_2\text{O}_5)$) can also be expected to increase for S-type granites and pegmatites with increasing fractionation (Chappell & White 1992). Upon careful inspection, concentrations of the trace elements of Li, Be, Cs, and Pb increase somewhat in the pegmatite from the southeast to the northwest. Similarly, the ASI shows a slight overall increase.

The variability in the trends can be explained by localized abundances of accessory mineral phases. In particular, this variable concentration trend stands out for sample site 12-GRANITE-S03 in which elevated P and F concentrations are observed (Fig. 4.4). These correlate with a high

abundance of apatite (Fig. 4.5). Locally abundant tourmaline is also likely responsible for the fluctuating concentration of B (Fig. 4.4 and 4.6). Local abundances of certain minerals, such as apatite and tourmaline, are likely caused by larger fluctuations in the geochemistry of the dike. Chondrite normalized concentrations of rare earth elements using values from McDonough & Sun (1995) show both positive and negative Eu anomalies irregularly spaced within the dike (Fig. 4.7). The Eu/Eu^* ratio reflects the variable Eu anomaly whereas the La/Yb ratio shows a slight overall decrease from the southeast to the northwest, following the general fractionation trend of the pegmatite (Fig. 4.8). This may indicate uneven fractionation within the dike or possibly localized accumulations of fluid-rich melt (T. Chudy, pers. commun.). An alternative explanation may be that the composition of the GRANITE pegmatite is closely linked to the variations of composition within the source material. According to Finger & Schiller (2012), a relatively horizontal spread within a Pb-Ba diagram (Fig. 4.9) may show that the composition of granitic rock is determined by the composition of the source rock with little fractionation occurring in the resulting magma.

In general, the geochemical data shows that the GRANITE pegmatite fractionates from the southeast to the northwest, in a manner consistent with S-type granites. The quantities of trace elements are highly variable, reflecting locally abundant minerals. It is possible that the patterns of mineralization could be controlled either by fluctuating degrees of fractionation within the dike, localized fluid accumulation, or perhaps mirroring the composition of the original source rock. The relatively small size of the samples also likely contributes to the large variation in concentration of some elements.

Figure 4.1: Location of sample sites for whole rock geochemistry. For a full explanation of the map contents, please see Appendix A.

Table 4.1: Major element whole rock geochemistry for the GRANITE pegmatite (samples organized from east to west).

Sample	12- GRANITE- S01	12- GRANITE- S05	12- GRANITE- S02	12- GRANITE- S03	12- GRANITE- S04	12- GRANITE- S06	12- GRANITE- S07	12- GRANITE- S08	12- GRANITE- S09
Description	Pegmatite*	Pegmatite	Foliated Pegmatite [§]	Pegmatite	Pegmatite	Pegmatite	Pegmatite	Pegmatite	Pegmatite
P ₂ O ₅ wt. %	0.052	0.103	0.067	1.322	0.115	0.11	0.074	0.119	0.148
SiO ₂	71.08	71.79	73.64	70.53	72.65	73.22	74.22	73.23	72.63
TiO ₂	0.04	0.02	0.04	0.01	0.01	0.03	0.03	0.02	0.01
Al ₂ O ₃	16.83	15.14	15.17	14.99	14.59	14.35	14.72	14.66	14.54
Cr ₂ O ₃	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fe ₂ O ₃	0.18	0.10	0.15	<0.01	0.05	0.06	0.26	<0.01	0.04
MgO	0.38	0.09	0.26	0.11	0.17	0.09	0.11	0.17	0.13
CaO	2.33	0.76	1.32	3.16	0.26	0.34	0.36	0.94	0.23
MnO	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01
FeO	0.70	0.32	0.57	0.38	0.64	0.32	0.45	0.45	0.32
Na ₂ O	4.46	2.45	2.88	3.01	2.08	2.16	3.59	2.57	1.88
K ₂ O	2.73	8.24	4.88	5.70	8.53	8.54	4.99	6.75	9.22
BaO	0.03	0.04	0.03	0.02	0.05	0.05	0.02	0.02	0.04
SrO	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
LOI	0.73	0.70	0.84	0.47	0.50	0.40	0.89	0.68	0.32
Total	99.55	99.76	99.86	99.73	99.66	99.68	99.72	99.62	99.52

Note: Sample analyses were conducted by ALS Minerals in North Vancouver, B.C. The samples were analyzed for the major elements using XRF; the amount of FeO was established by H₂SO₄-HF acid digestion and titrimetric finish. *Pegmatite sample from small dike occurring directly beneath the main dike. [§]Foliated pegmatite part of the main dike with an appearance similar to an orthogneiss.

Table 4.2: Minor element whole rock geochemistry for the GRANITE pegmatite (samples organized from east to west).

Sample	12- GRANITE- S01	12- GRANITE- S05	12- GRANITE- S02	12- GRANITE- S03	12- GRANITE- S04	12- GRANITE- S06	12- GRANITE- S07	12- GRANITE- S08	12- GRANITE- S09
Description	Pegmatite*	Pegmatite	Foliated Pegmatite [§]	Pegmatite	Pegmatite	Pegmatite	Pegmatite	Pegmatite	Pegmatite
Li [†] ppm	9.3	14.4	63.5	15.9	18.6	15.3	8.1	7.2	5.4
Be [†]	6.8	3.6	3.99	8.26	2.63	3.03	4.92	7.62	21
B	1520	140	<20	90	670	300	20	540	530
F	140	60	150	1000	140	80	100	80	100
Cl	<200	<100	200	<200	240	150	<200	<100	<100
Sc [†]	1.2	1.2	1.7	1	1.3	1.1	1.5	1.9	1.3
V [†]	3	1.0	4	1	2	1	2	1	1
Cr [†]	10	7	8	7	4	7	6	14	6
Mn [†]	94	53	88	193	83	52	82	58	59
Co [†]	0.8	0.4	0.7	0.4	0.5	0.4	0.6	0.3	0.3
Ni [†]	1.8	0.7	1.3	0.6	1	0.7	0.9	0.8	0.5
Cu [†]	4.8	2.9	0.7	2.2	1.4	1.5	3	1.1	2.9
Zn	12	6	11	5	7	6	7	5	6
Ga [†]	14.9	11.5	13.75	15.75	11.8	11.45	12.9	14	12.55
Ge [†]	0.13	0.15	0.14	0.16	0.13	0.15	0.17	0.17	0.16
As [†]	1.4	0.8	1.7	0.6	2.6	0.7	0.7	<0.2	<0.2
Se [†]	<1	<1	<1	<1	<1	<1	<1	<1	<1
Rb	78.9	208	136.5	147.5	220	225	145	160.5	234
Sr	120.5	88.1	92.2	77.5	85.9	90.5	74.5	77.4	80
Y	21.3	15.8	45.9	24.7	13.4	30.7	43.5	21.6	5.4
Zr	60	24	72	15	9	12	22	17	4
Nb	2	3.7	3.4	4.4	3.9	5.5	4	6.3	4
Mo [†]	0.64	0.47	0.56	0.52	0.3	0.46	0.33	0.92	0.37
Ag [†]	0.02	0.01	0.06	0.01	0.03	0.02	0.06	0.01	0.02
Cd [†]	0.05	0.04	0.09	0.18	0.04	0.02	0.05	0.04	0.02
In [†]	0.008	0.005	0.009	0.005	0.005	0.006	0.005	<0.005	<0.005
Sn [†]	2.9	3.9	4.7	3.2	3.1	3.1	2.6	2.6	2.3
Sb [†]	0.07	0.06	0.06	0.05	0.08	<0.05	0.06	0.06	0.05
Te [†]	0.08	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Cs	1.73	6.86	2.21	2.56	8.48	5.59	2.66	3.41	7.05
Ba	362	384	361	332	507	515	319	248	428
La	9.4	4.1	15	6.1	5.4	5.1	14.5	5.2	1.8
Ce	18.2	7.9	31.1	14.9	10.8	10.5	30.8	10.2	3.1
Pr	2.1	0.89	3.56	1.98	1.25	1.16	3.61	1.17	0.35
Nd	7.2	3.2	12.8	7.4	4.2	4.2	12.8	4.1	1.3
Sm	1.74	0.93	3.15	2.78	1.27	1.38	3.4	1.33	0.48
Eu	0.76	0.6	0.66	0.68	0.61	0.61	0.67	0.44	0.52
Gd	1.95	1.26	3.51	3	1.35	2.08	3.81	1.61	0.59
Tb	0.43	0.3	0.77	0.66	0.29	0.52	0.88	0.4	0.13
Dy	3	2.29	5.74	4.16	2.01	4.02	6.38	2.9	0.88
Ho	0.67	0.49	1.37	0.79	0.42	0.9	1.36	0.61	0.17
Er	2.15	1.58	4.39	2.32	1.33	2.89	4.33	2.01	0.53
Tm	0.36	0.31	0.79	0.43	0.25	0.54	0.81	0.38	0.1
Yb	2.24	2.17	5.53	3.03	1.75	3.84	5.65	2.81	0.81
Lu	0.32	0.31	0.78	0.41	0.25	0.55	0.79	0.41	0.12
Hf	1.9	0.9	2.3	0.8	0.5	0.6	1	0.9	0.5
Ta	0.3	0.6	0.2	1	2.4	1.1	0.6	2.6	2.2
W [†]	0.3	1	0.5	0.6	0.8	1	0.9	0.5	0.5
Re [†]	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Tl [†]	0.37	0.94	0.6	0.71	1.02	1.01	0.61	0.66	1.02
Pb [†]	46.2	66.7	43.8	55.6	73	97.3	60.7	58.1	89
Bi [†]	0.08	0.12	0.1	0.29	0.34	0.16	0.13	0.08	0.13
Th	3.17	1.75	9.63	.95	2.06	2.17	7.27	2.8	0.64
U	2.42	2.2	6.1	5.68	5.29	5.38	5	2.55	1.77
CO ₂ %	0.2	0.3	<0.2	<0.2	<0.2	<0.2	<0.2	0.2	<0.2
H ₂ O ⁻	0.14	0.14	0.18	0.12	0.14	0.09	0.21	0.14	0.07
H ₂ O ⁺	0.02	0.44	0.69	0.24	0.33	0.17	0.68	0.3	0.13

Note: Sample analyses were conducted by ALS Minerals in North Vancouver, B.C. B was determined by NaOH fusion and ICP finish. F was determined by S.I.E. Cl was determined by NAA (elevated detection limits due to high Na and Al). CO₂ was determined by coulometer. H₂O⁻ was found by gravimetric procedure after drying at 105°C. H₂O⁺ was determined by combustion furnace followed by infrared spectroscopy. All other elements were determined by four acid digestion and ICP-MS (denoted with [†]) or lithium metaborate fusion and ICP-MS techniques. *Pegmatite sample from small dike occurring directly beneath the main dike. [§]Foliated pegmatite part of the main dike with an appearance similar to an orthogneiss.

Figure 4.2: Element ratios indicating increasing fractionation to the northwest for the GRANITE pegmatite.

Figure 4.3: Other fractionation indicators (concentrations of Li, Be, Cs, and Pb and the ASI ratio), show subtle increases in fractionation from the southeast to the northwest.

Figure 4.4: The spike in concentration of P and F at sample 12-GRANITE-S03 is likely caused by the abundant apatite observed in the sample. Likewise, the variable concentration B correlates with observed abundances of tourmaline observed in the field and hand sample. B was below the detection limit for 12-GRANITE-S02.

Figure 4.5: A representative hand sample from 12-GRANITE-S03 in plain light (top) and under short-wave UV light (bottom). Apatite is nearly colorless under plain light and fluoresces orange yellow under short-wave UV light. Black minerals in plain light are tourmaline and biotite. The abundance of apatite at this site likely contributed to elevated P and F concentrations.

Figure 4.6: A representative hand sample from 12-GRANITE-S09 plain light (top) and under short-wave UV light (bottom). Black minerals in plain light are tourmaline crystals. Apatite is nearly colorless under plain light and fluoresces orange yellow under short-wave UV light. . The abundance of tourmaline at this site likely contributed to elevated B concentrations.

Figure 4.7: Chondrite normalized concentrations of the rare earth elements including Y. Note the both strongly positive and negative anomaly for Eu.

Figure 4.8: The Eu/Eu* and La/Yb ratios.

Figure 4.9: Pb-Ba diagram showing a relatively horizontal spread of values.

Chapter 5: Mineralogy

A wide range of the principal minerals of the pegmatites were examined in hand sample and in thin section combined with the use of a scanning electron microscope (SEM) equipped with an energy-dispersion X-ray spectrometer (EDS), and an electron microprobe (EMP). Some mineral phases, such as phosphates and secondary minerals, were identified using single crystal and powder X-Ray diffraction before being studied with the SEM and EMP. This was done in order to identify the minerals present within the dikes and to delineate fractionation trends within the pegmatite field. The methodology and full results of these analyses can be found in Appendix B, C, and D.

5.1 Tourmaline

Tourmaline was examined in detail because it is well suited to charting pegmatite fractionation as it can accommodate numerous varieties of elements in its crystal structure. Growing tourmaline crystals incorporate new elements into its structure based upon the evolving bulk composition of the cooling pegmatite melt and minute compositional fluctuations at the crystal-melt boundary (van Hinsberg et al. 2011). The tourmaline supergroup has the following general formula, site coordinations, and common substitutions:

Classification of tourmaline is based first on the occupancy of the X site, then on occupancy in the W site, and lastly on the occupancy of the Y site (Henry *et al.* 2011, van Hinsberg *et al.* 2011).

The tourmaline species present in a pegmatite vary somewhat by the composition of the host rock and by the pegmatite type. Composition of tourmaline can be influenced by fluids circulating into the pegmatite from the host rock. It is not unreasonable to expect that the tourmaline will be enriched in the same elements as the host rock (Selway 1999).

The composition of the pegmatite melt is usually a greater controlling factor in tourmaline evolution rather than fluid circulation from the host rock. For example, in lepidolite subtype pegmatites, the tourmaline species expected to be present are foitite-schorl, schorl-foitite, elbaite-schorl, elbaite, elbaite-rossmanite, rossmanite-elbaite, and elbaite from the outermost to innermost zones of the pegmatite, respectively (Selway 1999). In more primitive pegmatite types, the tourmaline species can be expected to be fairly uniform and homogeneous, existing mainly as part of the schorl-dravite series (Robles *et al.* 1999, Lottermoser & Lu 1997).

5.1.1 Description

Generally, the tourmaline in the study area is black and ranges from very fine (<1mm; border zones and JAN aplites) to very coarse grained (~30 cm long; BERYL pegmatite). Colored tourmaline can be perceived in the core zones of the CORD (blue), GARPPOS (black with green rims), LI and LI2 (black with blue-green rims, pink, and green) pegmatites. Crystals are usually discrete rather than intergrowths or aggregates, oriented perpendicular to the border zones or xenoliths, prismatic, subhedral to euhedral, and apparently homogeneous. Tourmaline crystals from the JAN aplites and from the central portions of many pegmatites have orientations that appear to be more random. Blue tourmaline aggregates were observed in the CORD pegmatite and tourmaline-quartz intergrowths were relatively common features in the GRANITE and WOBBLE pegmatites.

Another common feature to all tourmaline specimens from the study area is well-developed parting. In most samples examined, at least two parting planes were encountered: a very strongly developed parting plane perpendicular to the *c* axis and a lesser-developed parting plane oriented subparallel to the *c* axis. The partings are occasionally filled with secondary micas, iron

oxides, and quartz (Fig. 5.1). The development of partings indicates that there was deformation throughout the field sometime after the tourmaline crystallized.

Figure 5.1: A BSE image of a tourmaline crystal from the BERYL pegmatite in which secondary mica and Fe-oxides can clearly be seen within the vertically and horizontally oriented partings.

Typically it is difficult to see any features (such as zoning) that might be indicative of chemical change of the environment surrounding it during crystallization in hand sample but it can be seen in the more fractionated pegmatites. As already mention above, the GARPHOS pegmatite contains crystals of tourmaline with black cores and green rims; in the slender pink and green tourmaline from the LI and LI2 pegmatites, white to pale pink cores in green tourmaline and clear rims on pink tourmaline can be distinguished.

Despite being difficult to observe in most areas in the field, zoning is a relatively common feature of the tourmaline and is often revealed in thin section or in back-scattered electron (BSE)

images (Fig. 5.2). The chemical zoning is most pronounced in the X_{Mg} ratio [$X_{Mg} = Mg / (Mg + Fe + Mn)$] in geochemically primitive pegmatites; the tourmaline from Li-bearing fractionated pegmatites also exhibits high variations in the X_{Mn} ratio [$X_{Mn} = Mn / (Mg + Fe + Mn)$] and contents of Li + Al.

Figure 5.2: Left: Zoning seen in a thin section of a tourmaline crystal that appeared homogeneous in hand sample from BERYL. Field of view is 10 mm. Right: Light gray wavy zoning seen in a BSE image of tourmaline crystal that appeared homogeneous in hand sample from GRANITE.

Another feature that is shared by many tourmaline crystals and is difficult to see while in the field is the incorporation of inclusions. While more infrequent than the presence of zoning, tourmaline crystals can sometimes contain inclusions of quartz, feldspar, primary biotite (partially replaced by the surrounding tourmaline), zircon, monazite, xenotime, columbite, and on very rare occasions bismutotantalite (Fig. 5.58).

Tourmaline crystals were examined from the BERYL, CORD, GAR, GARMUS, GARPPOS, GARTOUR, GRANITE, JAN, JUNCT, LENS, LENS2, LI, LI2, LONG, MUSC, PEGMA, POCKET, SIMPLE, SIMPLE2, SIMPLE3, SIMPLE4, SIMPLE5, SIMPLE6, SIMPLE7, SIMPLE9, SIMPLE11, SIMPLE12, SIMPLE13, SIMPLE14, SIMPLE16, SIMPLE17, SMALL, THIN, TOUR, TOURMUS, WOBBLE, and ZONED pegmatites.

5.1.2 The BERYL Pegmatite Tourmaline

Border zone tourmaline from the BERYL pegmatite is Mg-rich schorl with the highest X_{Mg} (~ 0.5) and OH contents from all tourmalines sampled in the pegmatite (Fig. 5.3). The tourmaline from the wall zone and intermediate zones (schorl, foitite, fluor-schorl) generally show increased X-site vacancy (towards foitite), Fe and Mn relative to the border zone tourmaline, as well as the calculated Li contents. In individual crystals, the F, Na, and Fe contents increase from the crystal core to the rim, changing from foitite to schorl to fluor-schorl. Tourmaline from the core of the pegmatite has the highest Fe content and shows a similar trend. The composition of the border zone tourmaline suggests Mg contamination of the primitive (low initial F content) pegmatite melt from the host rock. The tourmaline from the wall, intermediate, and core zones follows the fractionation of Fe/Mg, F and Li in the melt; contents of Fe, Li, and F increase from the pegmatite border to the core.

Figure 5.3: Ternary diagrams showing the classification of tourmaline sampled from the BERYL dike.

5.1.3 The CORD Pegmatite Tourmaline

The examined tourmaline samples from the CORD pegmatite are compositionally zoned with Na, Mg-rich cores and $X_{\square}$, Fe-enriched rims (Fig. 5.4). The composition changes from dravite in crystal cores to schorl and foitite in crystal rims. The high calculated Li contents for all samples suggest that the pegmatite may be more fractionated than seen in this study. Some of the tourmaline samples from the center of the pegmatite are dark blue in color (Fig. 3.5c). Blue dravite with low levels of Fe^{3+} and Ti is typical for low-Li pegmatites as reported by Novák (1998).

Figure 5.4: Ternary diagrams showing the classification of tourmaline sampled from the CORD dike.

5.1.4 The GAR Pegmatite Tourmaline

Tourmaline studied from the GAR pegmatite is Na-rich and exhibits some compositional zoning, with increasing Fe content from the pegmatite border zone to the core; the composition changes from dravite to schorl (Fig. 5.5). Zoned tourmaline that is replacing sekaninaite follows the opposite trend with Fe-rich cores (schorl) and Mg-rich rims (Fe-rich dravite).

Ca, Al and ^WO contents are greater in the border zone tourmaline than in the other tourmaline samples examined. Tourmaline from the core zone of the pegmatite displays increasing Na and F contents from core to rim; tourmaline replacing sekaninaite shows increasing F from core to rim.

Figure 5.5: Ternary diagrams showing the classification of tourmaline sampled from the GAR dike.

5.1.5 The GARMUS Pegmatite Tourmaline

GARMUS pegmatite tourmaline samples are Na-rich and exhibit compositional zoning, with increasing Fe content from the pegmatite border zone to the wall zone; the composition changes from dravite to schorl (Fig. 5.6).

Mg, Ca, and F contents are greater in the border zone tourmaline than in the other tourmaline samples examined. Tourmaline from the wall zone of the pegmatite displays lower Na and F contents in crystal cores compared to the border zone and shows a slight Na, Ca, and F enrichment from core to rim.

Despite its high fractionation level (presence of beryl, columbite, and spessartine) the composition of tourmaline is relatively primitive, possibly because the pegmatite does not have tourmaline in its core.

Figure 5.6: Ternary diagrams showing the classification of tourmaline sampled from the GARMUS dike.

5.1.6 The GARPPOS Pegmatite Tourmaline

Tourmaline samples from border zone of the GARPPOS pegmatite are Ca- and Mg-rich relative to all other samples; samples from the intermediate zone of the pegmatite have slightly elevated Ca and Mg contents compared to tourmaline samples from the core zone (Fig. 5.7a). All tourmaline crystals exhibit compositional zoning, with increasing X_{Fe} and OH content from the crystal core to rim in the border and intermediate zones of the pegmatite. Composition of the tourmaline from the pegmatite border zone to the wall zone changes from dravite to Fe-rich dravite and Mg-schorl from crystal core to rim.

Figure 5.7a: Ternary diagrams showing the geochemistry of tourmaline sampled from the GARPPOS dike.

Core zone tourmaline samples are significantly zoned with black cores and green rims in hand sample (Fig. 3.10c). In thin section the cores are blue-brown and rimmed with green, blue, yellow, and colorless zones. Six different textural and compositional types were distinguished (Fig. 5.7b): tourmaline I (tur I) is present as blue-brown cores rimmed by dark green tourmaline II (tur II); tourmaline III (tur III) forms a narrow blue zone (distinguishable only in the largest of the collected crystals) rimmed by yellow, inclusion-rich tourmaline IV (tur IV); tourmaline V (tur V) is colorless and often forms skeletal overgrowths on tourmaline IV; and tourmaline VI (tur VI) is present as skeletal replacement and fracture filling in earlier tourmaline generations.

Figure 5.7b: A tourmaline from the GARPHOS core zone in thin section using plain light with the tourmaline types labeled. The crystal is 24 mm × 17 mm.

Tourmaline I is Mg-rich schorl-foitite in crystal cores; the Na, ^TAl (tetrahedrally coordinated Al), ^YAl (Y site Al), X_{Fe} , and X_{Mn} increases towards the crystal rims (Fig. 5.7c). The green tourmaline II is schorl-foitite; has increased amount of Li, Na, ^TAl , ^YAl , and X_{Mn} ; and decreased amounts of Fe and Mg compared to tourmaline I. Composition of tourmaline III seems to represent the most evolved stage of tourmaline II and therefore may only a represent color variant of tourmaline II.

Overall, the yellow, inclusion-rich tourmaline IV is (Fe,Mn)-rich elbaite and shows a decrease in ^TAl , Fe, and Mg and increases in Na, Mn, ^YAl , and Li compared to tourmaline II and III (Fig. 5.7c). It generally evolves towards Fe-poor and Mn-rich compositions; some of the rims display a slight increase of Fe, Mg, and ^YAl and a decrease in Mn. This suggests partial dissolution of earlier generations (or some Fe-Mg phase in the pegmatite core) causing similar composition trends as those seen for tourmaline VI.

Tourmaline V is elbaite and exhibits increases in Na, Li, Mn, and ^YAl while showing decreases in Fe, Mg, and ^TAl compared to all other types. Tourmaline VI is schorl-elbaite and displays a decrease in Li, ^YAl and Mn while showing an increase in Fe and Mg relative to most earlier crystallized elbaite. It is enriched in Na and ^TAl , similar to that of tourmaline V; its Fe enrichment can be explained by dissolution of the earlier host tourmaline types (Fig. 5.7c).

Figure 5.7c: Plots showing the compositional trends of the different tourmaline types.

5.1.7 The GARTOUR Pegmatite Tourmaline

The tourmaline sample examined from the GARTOUR pegmatite exhibits compositional zoning with increasing Na, Mg, and F contents towards the rim from the core of the crystal. Composition of the crystal is foitite-schorl in the core and changes to dravite in the rim (Fig. 5.8a).

Figure 5.8a: Ternary diagrams showing the classification of tourmaline sampled from the GARTOUR dike.

Unlike the tourmaline from most other pegmatites, the compositional zoning is inverted, i.e., schorl to dravite, rather than dravite to schorl as seen in most other pegmatites. Close inspection of the BSE image (Fig. 5.8b) reveals the outermost rim to be a euhedral overgrowth on the inner rim and core. This suggests the possibility the outer rim tourmaline is a separate generation from the core of the crystal and opening of the system to Mg contamination from the host rock.

Figure 5.8b: A BSE image of the tourmaline from the GARTOUR pegmatite with the core, inner rim and outer rim indicated.

5.1.8 The GRANITE Pegmatite Tourmaline

Tourmaline from the GRANITE pegmatite was sampled along the length of the dike (520 m) from the same locations the whole rock geochemistry and feldspar samples were gathered. There was not any tourmaline evident at sample site 12-GRANITE-S02.

Despite the overall fractionation trends of the dike from the southeast to the northwest, the tourmaline composition shows only a little variation. Tourmaline crystals are mainly homogeneous with oscillatory zoning observed only rarely (Fig. 5.9a). Within the concentrated scatter of the data, there is a slight increase of the Fe content from the southeast to the northwest, consistent with the geochemical trend of the dike. The tourmaline compositions range from dravite with a high ^{18}O component to schorl. The elevated Ca and generally high Mg contents could result from contamination from the host rock (Fig. 5.9b).

The highest Fe contents were found in the tourmaline samples from 12-GRANITE-S06 (which shows oscillatory zoning; Fig. 5.9a) and 12-GRANITE-S07 (samples include tourmaline from the main GRANITE pegmatite and a tiny, very coarse grained branch ~15 cm wide and 1.5 m long). Both of these localities have fluctuating contents of Fe^{2+} , Fe^{3+} , Mg, $^{\text{Y}}\text{Al}$, $^{\text{T}}\text{Al}$, and Na (Fig. 5.9c). Compared to other pegmatites, the overall degree of fractionation of Mn, Fe, and Mg in tourmaline is low.

Figure 5.9a: A BSE image of a tourmaline crystal from 12-GRANITE-S06 showing oscillatory zoning. Bright white grain on the right edge of the crystal is a zircon.

Figure 5.9b: Ternary diagrams showing the geochemistry of tourmaline samples from the GRANITE dike.

Figure 5.9c: Diagrams highlighting the fluctuating geochemistry in tourmaline samples from the 12-GRANITE-S06 and 12-GRANITE-S07 sample sites. Symbols are the same as those in Fig. 5.9a.

5.1.9 The JAN Aplites Tourmaline

Tourmaline from the JAN aplite has distinct textural zoning (Fig. 5.10a) except for the homogeneous tourmaline from the border zone which is Ca- and Mg enriched and F-poor compared to zoned tourmaline from wall zone and the cores of the tourmaline from the center of the aplite. It has a composition of Mg-rich schorl (Fig. 5.10b).

The white core of the zoned tourmaline from the wall zone (Fig. 5.10a) has high $X_{\square}$ and X_{Fe} , and high calculated Li. Its blue rim is more Na-rich with elevated Ca, lower X_{Fe} , and no Li. It has a composition of Li-rich schorl to foitite changing to Mg-rich schorl (Fig. 5.10b).

The dark blue core of the zoned tourmaline from the center of the pegmatite (Fig. 5.10a) has variable contents of Na and $X_{\square}$, low Ca (< 0.1 apfu Ca), and high X_{Fe} ~ 0.7 to 0.95 and can be classified as schorl. The green middle zone is Ca-enriched (~ 0.15 to 0.27 apfu) and Mg-rich ($X_{Mg} \sim 0.70$) compared to the crystal core; it can be classified as Ca-rich dravite. The dark green rim of the crystal is even more enriched in Ca (~ 0.35 to 0.40 apfu) and has slightly decreased contents of Mg ($X_{Mg} \sim 0.63$); it belongs to Ca,Fe-rich dravite, close to the uvite boundary (Fig. 5.10b).

Figure 5.10a: The tourmaline with the white core and dark blue rim on the left is from the wall zone and is ~ 1.5 mm long. The two green-rimmed crystals with the dark blue cores are from the center of the aplite; the combined length of the green-rimmed crystals is ~ 1.2 mm.

Figure 5.10b: Ternary diagrams showing the classification of tourmaline sampled from the JAN aplites.

The tourmaline from the JAN aplite shows distinct zoning (Fig. 5.10a) strongly resembling that of the schorl-elbaite tourmaline seen in some of the GARPPOS samples but its compositional zoning is based on distinctly different factors. Its initial X_{Fe} is unusually high compared to the other pegmatites in the study area, suggesting a high degree of melt fractionation, which is also supported by the garnet composition (almost pure spessartine) from this locality. The middle and rims of the tourmaline crystals indicate strong enrichment in Ca and Mg without an increase in F. This is most likely due to contamination of late-stage fluids from the host rock.

5.1.10 The JUNCT Pegmatite Tourmaline

The border zone tourmaline sample (Fe-rich dravite) examined from the JUNCT pegmatite exhibits high Ca and Mg compared to the crystal core of the tourmaline sample from the core zone of the pegmatite (Mg-rich schorl). The crystal rim of the core zone tourmaline shows increased Ca and Mg compared to the crystal core, indicating contamination from the host rock (Fig. 5.11).

Figure 5.11: Ternary diagrams showing the classification of tourmaline sampled from the JUNCT pegmatite.

5.1.11 The LENS Pegmatite Tourmaline

Tourmaline sampled from the LENS pegmatite is schorl with a zone of Fe-rich dravite. The border zone sample is Mg-rich in comparison to most of the tourmaline from the center of the pegmatite (Fig. 5.12a). The extreme variation of X_{Mg} together with an increase in the F content in the rim of one of the centrally located tourmaline crystals is most probably caused by oscillatory zoning in the late generation of tourmaline (Fig. 5.12b).

Figure 5.12a: Ternary diagrams showing the classification of tourmaline sampled from the LENS pegmatite.

Figure 5.12b: A BSE image of tourmaline from the LENS pegmatite. Very faint oscillatory zoning can be seen in the middle of the crystal (late generation).

5.1.12 The LENS2 Pegmatite Tourmaline

Tourmaline from the border zone of the LENS2 pegmatite is Ca, F-rich dravite with a high oxy-dravite and uvite component while tourmaline from the center of the pegmatite shows compositions of both ^WO, Fe-rich dravite and ^WO, Mg-rich schorl (Fig. 5.13).

Figure 5.13: Ternary diagrams showing the classification of tourmaline sampled from the LENS2 pegmatite.

5.1.13 The LI Pegmatite Tourmaline

Black tourmaline sampled from the core zone of the LI pegmatite is zoned in thin section (Fig. 5.14a) has a large violet-gray core with a wide gray-brown rim overgrown with colorless to pale blue skeletal tourmaline. The crystal core is foitite-schorl and increases in Na, Li, Fe, Mn, and F towards schorl in the gray-brown rim and continues to fluor-elbaite in the skeletal overgrowth.

Figure 5.14a: Black zoned tourmaline from the LI pegmatite as seen in thin section using plain light. Crystal is ~ 16 mm wide by 15 mm tall.

Other tourmaline crystals sampled from the pegmatite core are pale green, pale pink, or colorless; they occur as isolated subhedral, prismatic crystals in albite and quartz. All are fluor-elbaite; cores are Na, Fe, F-rich (Fig. 5.14b) while the rims are gradually depleted in Na and Fe, with increasing X_{Mn} (Fig. 5.14c). Outer rims of the fluor-elbaite crystals usually show a decrease in F and Ca and a compositional trend towards rossmanite; some of the crystal rims also display a slight enrichment in Ca and F (liddicoatite component; Fig. 5.14c).

Figure 5.14b: Ternary diagrams showing the classification of tourmaline sampled from the LI pegmatite.

Figure 5.14c: Plots showing the geochemical evolution of tourmaline sampled from the LI pegmatite.

5.1.14 The LI2 Pegmatite Tourmaline

Tourmaline from the LI2 dike was sampled from the wall zone to the core zone; wall zone and intermediate tourmaline is black in hand sample while the tourmaline from the core zone is black, blue, green, pink, and colorless in hand sample.

The wall zone and intermediate zone tourmaline is ^WO, Mg-rich compared to tourmaline from the core of the pegmatite; their compositions range from Fe-rich dravite to Mg-rich schorl (Fig. 5.15a).

Black tourmaline sampled from the pegmatite core is Fe-rich with increasing Mn, Li, and F contents from crystal core to rim. Composition of the black tourmaline samples have schorl cores transitioning to elbaite-schorl and then changing to fluor-elbaite rims (Fig. 5.15a).

Tourmaline with colors other than black from the core of the pegmatite show increased Li, Mn, and F compared to all other sampled tourmaline. The crystal cores are typically Na, Fe, F-rich compared to the crystal rims, which show an increase in $X_{\square}$, and Mn and a decrease in Na, F and Ca. Some of the crystal rims show a slight increase of Ca and F towards the liddicoatite component. Overall, the compositions range from elbaite to fluor-elbaite and to rossmanite.

In the cores of some of the green tourmaline samples, an increase in the Bi content (up to 0.96 wt. % Bi₂O₃; 0.04 apfu Bi) was noted.

Figure 5.15a: Ternary diagrams showing the classification of tourmaline sampled from the LI2 pegmatite.

Figure 5.15b: Plots showing the geochemical evolution of tourmaline sampled from the LI2 pegmatite.

5.1.15 The LONG Pegmatite Tourmaline

Tourmaline from the border zone of the pegmatite and the crystal core of the tourmaline from the center of the dike is Ca- and Fe-rich dravite (Fig. 5.16a). The middle and rim of the tourmaline crystal (Fig. 5.16b) from the center of the pegmatite displays increasing Fe and Na contents; the middle of the crystal is more $^{\text{W}}\text{OH-}$ and $^{\text{W}}\text{O-}$ rich than the crystal rim and crystal core which are slightly more F-rich. Late tourmaline filling fractures (5.16b) in the tourmaline shows a slight increase in the Ca and $^{\text{W}}\text{OH}$ contents compared to the tourmaline crystal rim (Fig. 5.16a). Compositionally, the tourmaline crystal analyzed from the center of the pegmatite changes from Fe-rich dravite to Mg-rich schorl from core to late stage fracture fill (Fig. 5.16).

Figure 5.16a: Ternary diagrams showing the classification of tourmaline sampled from the LONG pegmatite.

Figure 5.16b: A BSE image of a tourmaline crystal from the center of the LONG pegmatite.

5.1.16 The MUSC Pegmatite Tourmaline

Tourmaline from the MUSC pegmatite appears to be homogeneous in hand sample and in BSE images. It displays slightly elevated contents of Ca and ^{18}O ; its overall composition is Mg-rich schorl (Fig. 5.17).

Figure 5.17: Ternary diagrams showing the classification of tourmaline sampled from the MUSC pegmatite.

5.1.17 The PEGMA Pegmatite Tourmaline

Tourmaline from the PEGMA pegmatite shows compositional zoning in tourmaline crystals sampled from the border zone and the center of the pegmatite. Border zone tourmaline exhibits slightly elevated $X_{\square}$, Ca, and ^WOH compared to tourmaline from the center of dike. Some of the crystal rims from the border zone tourmaline display increased Ca and F contents compared to the crystal cores. Its composition varies from $X_{\square}$, Ca, Fe-rich dravite to Mg-rich schorl (Fig. 5.18).

Tourmaline sampled from the center of the dike shows slightly elevated contents of ^WO , Mn, and Na compared to the border zone tourmaline samples. The middles of the tourmaline crystals typically display increases of Fe, Mn, Ca, and ^WOH than the crystal cores. Crystal rims exhibit increased ^WO , F, Na, Fe, and Mn contents than the crystal middles. The composition of tourmaline from the center part of the dike varies from Fe-rich dravite to Mg-rich schorl (Fig. 5.18).

Fig. 5.18: Ternary diagrams showing the classification of tourmaline sampled from the PEGMA pegmatite.

5.1.18 The POCKET Pegmatite Tourmaline

The tourmaline crystal analyzed from the border zone has elevated Ca, Mg, and $^{\text{W}}\text{O}$ contents compared to the tourmaline from the center of the pegmatite. Its composition is Ca, and Fe-rich dravite with a high oxy-dravite component (Fig. 5.19).

Tourmaline examined from the center of the pegmatite displays crystal cores with increased $^{\text{X}}_{\square}$ and Fe contents compared to the border zone. One of the crystal cores exhibits a much greater $^{\text{W}}\text{OH}$ content than the other crystal core examined, which has a high $^{\text{W}}\text{O}$ content. The crystal rim of the tourmaline from the center of the pegmatite is Mg- and Na-rich compared to the crystal cores and also displays a slightly elevated $^{\text{W}}\text{O}$ and Ca content. The elevated content of Mg and the slight increase in Ca could be from the system opening to contamination from the host rock. The compositions of the tourmaline from the center of the pegmatite change from Mg-rich schorl-foitite with a high oxy-schorl component to Fe-rich dravite with a high oxy-dravite component (Fig. 5.19).

Figure 5.19: Ternary diagrams showing the classification of tourmaline sampled from the POCKET pegmatite.

5.1.19 The SIMPLE Pegmatite Tourmaline

Tourmaline sampled from the SIMPLE pegmatite is homogeneous in hand sample and in BSE images. Samples are Fe-rich dravite; they show slightly elevated Ca, $X_{\square}$, ^WO , and F contents and very elevated Fe contents than would be expected if samples were end-member dravite (Fig. 5.20).

Figure 5.20: Ternary diagrams showing the classification of tourmaline sampled from the SIMPLE pegmatite.

5.1.20 The SIMPLE2 Pegmatite Tourmaline

Tourmaline sampled from the SIMPLE2 pegmatite is homogeneous in hand sample and in BSE images; its composition straddles the boundary between schorl and dravite. The sample examined displays slightly elevated Ca, $X_{\square}$, and F content than might be expected for a crystal showing nearly an even mixture of end-member schorl and dravite (Fig. 5.20).

Figure 5.21: Ternary diagrams showing the classification of tourmaline sampled from the SIMPLE2 pegmatite.

5.1.21 The SIMPLE3 Pegmatite Tourmaline

The tourmaline crystal sampled from the center of the SIMPLE3 pegmatite is Ca and Fe-rich dravite and displays slight compositional zoning. The crystal core shows greater F and Mg contents and very slightly increased Na than the crystal rim; the crystal rim displays greater ^WOH and Fe contents and very slightly increased $X_{\square}$ compared to the crystal core (Fig. 5.22).

Figure 5.22: Ternary diagrams showing the classification of tourmaline sampled from the SIMPLE3 pegmatite.

5.1.22 The SIMPLE4 Pegmatite Tourmaline

The tourmaline sample from the center of the SIMPLE4 pegmatite is Ca, $X_{\square}$, and Fe-rich dravite with a minor oxy-dravite component and exhibits slight compositional zoning. The crystal rim has an increased content of Fe and ^WOH compared to the crystal core (Fig. 5.23).

Figure 5.23: Ternary diagrams showing the classification of tourmaline sampled from the SIMPLE4 pegmatite.

5.1.23 The SIMPLE5 Pegmatite Tourmaline

Tourmaline sampled from the SIMPLE5 pegmatite is homogeneous in hand sample and in BSE images. Its composition is Fe-rich dravite with a major oxy-dravite component; it displays slightly elevated $X_{\square}$ and Ca contents than an end-member dravite (Fig. 5.24).

Figure 5.24: Ternary diagrams showing the classification of tourmaline sampled from the SIMPLE5 pegmatite.

5.1.24 The SIMPLE6 Pegmatite Tourmaline

Tourmaline sampled from the SIMPLE6 pegmatite is homogeneous in hand sample and in BSE images. Its composition is Fe-rich dravite with slightly elevated contents of F, Ca, and $X_{\square}$ than might be expected in end-member dravite (Fig. 5.25).

Figure 5.25: Ternary diagrams showing the classification of tourmaline sampled from the SIMPLE6 pegmatite.

5.1.25 The SIMPLE7 Pegmatite Tourmaline

Tourmaline from the SIMPLE7 pegmatite displays compositional zoning. The crystal core has increased $X_{\square}$ and wO , a slightly elevated content of Mg, and slightly decreased content of Ca compared to points analyzed between the crystal core and rim which show elevated Ca, Fe, Na, and wOH contents and slightly decreased Mg contents. The crystal rim has increased $X_{\square}$, Fe, and wOH contents and decreased Na and Ca contents compared to the rest of the crystal. The overall composition of the crystal changes from Fe-rich dravite with a major wO component to Ca and Fe-rich dravite with a minor wO component to Mg- and $X_{\square}$ -rich schorl (Fig. 5.26).

Figure 5.26: Ternary diagrams showing the classification of tourmaline sampled from the SIMPLE7 pegmatite.

5.1.26 The SIMPLE9 Pegmatite Tourmaline

Tourmaline from the host rock in contact with the SIMPLE9 pegmatite displays compositional zoning and is Ca and Mg-rich compared to all tourmaline analyzed within the SIMPLE9 pegmatite. From the crystal core to the middle of the crystal, Fe and $X_{\square}$ contents increase; from the middle of the crystal to the crystal rim, Fe content continues to increase while the $X_{\square}$ and Ca contents decrease and the Na content increases. The composition of the host rock tourmaline is Ca- and Fe-rich dravite (Fig. 5.27a).

Tourmaline from the border zone of the SIMPLE9 pegmatite exhibits lower Ca and Mg contents and higher ^WOH and Fe contents compared to the host rock tourmaline. From the crystal cores to the rim, the $X_{\square}$ content increases. However, the crystal rims have the same Na content as their cores whereas the Fe content is higher. The composition of the border zone tourmaline transitions from Fe-rich dravite with a high magnesio-foitite component to Mg-rich schorl (Fig. 5.27a & b).

The tourmaline samples from the center of the pegmatite show lower Ca and Mg contents and higher Fe contents compared to the border zone and host rock tourmaline. From the crystal cores to the crystal rims, the Fe content increases along with a slight increase in the Li and Mn contents while the $X_{\square}$ content decreases slightly. Late stage overgrowth of tourmaline on the crystal rims (Fig. 5.27c) show an increase of Mg content and a very slight increase of Ca content compared to the crystal rim, possibly suggesting an opening of the system to contamination from the host rock. The composition of the tourmaline from the center of the pegmatite transitions from Mg-rich schorl to schorl from crystal cores to rims and towards Mg-rich schorl and dravite in the late stage overgrowth tourmaline (Fig. 5.27a & b).

Figure 5.27a: Ternary diagrams showing the classification of tourmaline sampled from the SIMPLE9 pegmatite.

Figure 5.27b: Plots showing the classification of tourmaline sampled from the SIMPLE9 pegmatite. Legend is the same as seen in Fig. 5.27a.

Figure 5.27c: Pale blue late overgrowth on tourmaline from the center of the SIMPLE9 pegmatite as seen in thin section using plain light. Field of view is 4.2 mm.

5.1.27 The SIMPLE11 Pegmatite Tourmaline

Tourmaline sampled from the SIMPLE11 pegmatite is homogeneous in hand sample and in BSE images. Its composition is Ca and Fe-rich dravite. One of the points analyzed shows an elevated content of ^{18}O and F compared to the other analytical point (Fig. 5.28).

Figure 5.28: Ternary diagrams showing the classification of tourmaline sampled from the SIMPLE11 pegmatite.

5.1.28 The SIMPLE12 Pegmatite Tourmaline

Tourmaline sampled from the center SIMPLE12 pegmatite displays compositional zoning; some of the zoning is oscillatory. In general, the crystal cores show decreased Ca and Mg contents than the middle of the crystal and crystal rims. Some points from the middle of the crystal display greatly increased Fe contents and slightly elevated $X_{\square}$ and Ca contents compared to most other analyzed points. Crystal rims exhibit slightly elevated Ca and Mg contents compared to all other analyzed points, possibly suggesting an opening of the system to contamination from the host rock. W-site occupancy is variable for all analytical points examined. The general trend for the composition changes from Mg-rich schorl to schorl to Fe-rich dravite with slightly elevated Ca content than might be expected for end-member dravite (Fig. 5.29).

Figure 5.29: Ternary diagrams showing the classification of tourmaline sampled from the SIMPLE12 pegmatite.

5.1.29 The SIMPLE13 Pegmatite Tourmaline

The tourmaline sampled from the SIMPLE13 pegmatite is homogeneous in hand sample and in BSE images. The sample from the border zone of the pegmatite shows elevated Na, Ca, Mg, and F contents compared to the sample from the center of the pegmatite. Tourmaline from the center of the pegmatite displays increased $X_{\square}$, Mn, Fe, and ^WOH contents and decreased Ca and F contents compared to the tourmaline from border zone of the pegmatite. The composition for the sampled tourmaline is Mg-rich schorl for the border zone and schorl for the center of the pegmatite (Fig. 5.30).

Figure 5.30: Ternary diagrams showing the classification of tourmaline sampled from the SIMPLE13 pegmatite.

5.1.30 The SIMPLE14 Pegmatite Tourmaline

Tourmaline samples from the SIMPLE14 pegmatite display compositional zoning. The crystal core and middle from the border zone sample is $^{\text{W}}\text{O}$ and Mg-rich. The crystal rim shows an increase in $^{\text{W}}\text{OH}$ and Fe contents, a slight increase in $^{\text{X}}\square$ content, as well as a decrease in $^{\text{W}}\text{O}$ content. Its composition transitions from oxy-schorl-dravite to Mg-rich schorl with a high oxy-schorl component (Fig. 5.31).

The tourmaline samples from the center of the pegmatite have a crystal core that is Mg rich with slightly elevated Ca and Na contents and a crystal core that is Fe-rich with a slightly elevated $^{\text{X}}\square$ content. Both crystal cores have a high $^{\text{W}}\text{O}$ content compared to the crystal rim. The crystal rim displays increased Mg and $^{\text{W}}\text{OH}$ contents compared to the crystal core from the center of the pegmatite. Their compositions are Fe-rich dravite with a high oxy-dravite component and schorl with a high oxy-schorl component (Fig. 5.31).

Figure 5.31: Ternary diagrams showing the classification of tourmaline sampled from the SIMPLE14 pegmatite.

5.1.31 The SIMPLE16 Pegmatite Tourmaline

Tourmaline sampled from the center of the SIMPLE16 pegmatite displays compositional zoning with greatly increasing Ca, ^WO , and Mg contents and slightly increasing Na content from crystal core to rim. The crystal core has greater contents of Fe, ^WOH , and $^X\text{□}$ than the analytical points from the middle and rim of the crystal. Its composition transitions from Mg-rich schorl with a high oxy-schorl component to Fe-rich dravite with a high oxy-dravite component. This transition from schorl to dravite rather than dravite to schorl, as is common with most tourmaline in pegmatites may suggest system was open to contamination from the host rock in the later stages of crystallization (Fig. 5.32).

Figure 5.32: Ternary diagrams showing the classification of tourmaline sampled from the SIMPLE16 pegmatite.

5.1.32 The SIMPLE17 Pegmatite Tourmaline

Tourmaline sampled from the center of the SIMPLE17 pegmatite displays compositional zoning; the crystal cores have greater contents of Fe and $X_{\square}$ compared to most other analytical points. The crystal rim from one of the crystals is nearly identical to the crystal cores other than a very slight increase of the Mg content. The crystal rim and the middle analytical points of the other crystal show increasing Ca, Mg, and F compared its crystal core and analytical points from the other crystal, which show greater ^WO and ^WOH contents across all parts of the crystal. The compositions of the tourmaline crystals sampled from the center of the pegmatite are Mg-rich schorl with a high oxy-schorl component and Fe-rich dravite with a high oxy-dravite component transitioning to Mg and Ca-rich uvite with an elevated oxy-uvite component (Fig. 5.33).

Figure 5.33: Ternary diagrams showing the classification of tourmaline sampled from the SIMPLE17 pegmatite.

5.1.33 The SMALL Pegmatite Tourmaline

Tourmaline analyzed from the center of the SMALL pegmatite is homogeneous in hand sample and in BSE images; samples not analyzed in time for this thesis display optical zoning in thin section and the rims of these crystals are Mn-rich. The sample analyzed is Fe-rich dravite with slightly elevated Ca, F, and $X_{\square}$ than might be expected in end-member dravite (Fig. 5.34).

Figure 5.34: Ternary diagrams showing the classification of tourmaline sampled from the SMALL pegmatite.

5.1.34 The THIN Pegmatite Tourmaline

A tourmaline crystal from the border zone was examined from the THIN pegmatite, as tourmaline was not present within the core of the dike. The tourmaline sample is homogeneous in hand sample and in BSE image. Its composition is Fe-rich dravite with a greater Ca content than might be expected from end-member dravite (Fig. 5.35).

Figure 5.35: Ternary diagrams showing the classification of tourmaline sampled from the THIN pegmatite.

5.1.35 The TOUR Pegmatite Tourmaline

Tourmaline from the border zone of the pegmatite is compositionally zoned; the crystal core has increased Ca, $X_{\square}$, ^WO , and Mg compared to the crystal rim which has increased Na, Fe, ^WOH , and F. Its composition transitions from Fe and Ca-rich dravite with a high oxy-dravite component to Mg-rich schorl with a high oxy-schorl component (Fig. 5.36).

The tourmaline sampled from the center of the pegmatite appears to be homogenous in hand sample and BSE image; it is optically zoned in a thin section not analyzed in time for this thesis. Compared to tourmaline analyzed from the border zone, it has increased $X_{\square}$, and Fe and decreased Ca. Its composition is foitite-schorl with a high oxy-foitite-schorl component (Fig. 5.36).

Figure 5.36: Ternary diagrams showing the classification of tourmaline sampled from the SIMPLE11 pegmatite.

5.1.36 The TOURMUS Pegmatite Tourmaline

The tourmaline sample examined from the border zone of the TOURMUS pegmatite is homogeneous in hand sample and in BSE image. It has greater Mg, Ca, and ^WO than tourmaline from the center of the pegmatite. Its composition is $\text{X}_{\square}$ and Fe-rich dravite with a minor oxy-dravite component (Fig. 5.37).

Tourmaline samples from the center of the pegmatite are compositionally zoned with Na, and F contents increasing from the typically $\text{X}_{\square}$ and ^WOH -rich cores. Compared to the border zone, the tourmaline from the center of the pegmatite contains greater Fe, slightly elevated Mn, and in one sample, increasing Li from the middle of the crystal to the crystal rim. Their compositions range from Mg-rich schorl to Li-rich schorl with a high fluor-schorl component to Li-rich fluor-schorl (Fig. 5.37).

Figure 5.37: Ternary diagrams showing the classification of tourmaline sampled from the TOURMUS pegmatite.

5.1.37 The WOBBLE Pegmatite Tourmaline

Tourmaline sampled from the border zone of the WOBBLE pegmatite appears to be homogeneous in hand sample and in BSE images. Its composition is Fe and Ca-rich dravite with a high oxy-dravite component. Tourmaline sampled from the center of the WOBBLE pegmatite is compositionally zoned and shows decreased Na, Ca, and ^WO contents and increased ^XCa , ^WOH , and Fe contents compared to the border zone tourmaline. The Na content of the tourmaline increases from the crystal core to the rim. Its composition is Mg-rich foitite-schorl with a high oxy-schorl component (Fig. 5.38).

Figure 5.38: Ternary diagrams showing the classification of tourmaline sampled from the WOBBLE pegmatite.

5.1.38 The ZONED Pegmatite Tourmaline

Tourmaline sampled from the border zone and the center of the ZONED pegmatite appears homogeneous in hand sample and in BSE images. Tourmaline from the border zone has greater Na, Ca, F, and Mg contents than the tourmaline from the center of the pegmatite which has slightly greater $X_{\square}$, Fe, ^WOH , and ^WO contents than the border zone. The composition of both tourmaline samples is Fe-rich dravite (Fig. 5.39).

Figure 5.39: Ternary diagrams showing the classification of tourmaline sampled from the ZONED pegmatite.

5.2 Feldspars

The composition of K-feldspar was studied in detail because the content of Rb and Cs in K-feldspar can be used as markers of pegmatite fractionation. Most K-feldspar samples were perthitic and analytical points were carefully placed in K-feldspar only. In some samples the albite occurred as patchy alteration; these areas were avoided as well. In one sample from a tiny pocket in the LI2 pegmatite, late K-feldspar (adularia) was observed as euhedral skeletal crystals on albite (Fig. 5.40).

Figure 5.40: A BSE image of late K-feldspar (Kfs) on albite (Ab).

The contents of Rb and Cs in K-feldspar are very low, in most cases they are close to the detection limit of the EMP (Fig. 5.41); however, the most fractionated pegmatites still exhibit elevated contents of Rb and Cs. The GARMUS pegmatite displays elevated Cs contents with relatively low Rb contents; this might be due to the altered nature of the sample analyzed.

Most of the K-feldspar samples show elevated contents of P due to berlinite substitution ($P + Al \leftrightarrow 2Si$). The amount of berlinite substitution approximately matches the degree of

pegmatite fractionation. The analytical points with the highest P contents are from the SKINNY, GARPHOS, POCKET, and LI2 pegmatites (Fig. 5.41).

Maps of the elevated Cs and Rb contents (Fig. 5.42a & b) show a good match with the locations of the most fractionated pegmatites. In addition to showing fractionation trends in the area, the map of the elevated P contents (Fig. 5.42c) show a good match with major phosphate-bearing localities. The maps also suggest other pegmatites (LENS, PEGMA, SIMPLE13, and SKINNY) that might be worth further mineralogical investigations in the future.

Figure 5.41: Plots showing Rb₂O vs. Cs₂O and berlinite substitution in K-feldspar.

Figure 5.42a: Map showing where K-feldspar samples had the greatest concentrations of Rb.

Figure 5.42b: Map showing where K-feldspar samples had the greatest concentrations of Cs.

Figure 5.42c: Map showing where K-feldspar samples had the greatest concentrations of P.

5.3 Phyllosilicates

The composition of mica was studied in detail because the content of Rb and Cs in micas, in the same way as K-feldspar, can be used as markers of pegmatite fractionation. Samples were selected for analyses if they showed limited to no alteration and if they were coarse grained. A few muscovite samples were analyzed if they displayed a habit not typically encountered in the study area (Fig. 5.43). Muscovite samples from the core zone were chosen over biotite, if possible; if not, biotite was analyzed instead. A few biotite samples were analyzed from the border and intermediate zones of the pegmatites. The analyses show the micas belong to the series of biotite (annite/phlogopite-siderophilite/eastonite), lepidolite (trilithionite-polyolithionite), and muscovite-trilithionite (Fig. 5.44).

Figure 5.43: Photomicrograph of fine-grained muscovite from the SKINNY pegmatite with a habit that is unusual for the study area. Dashed black line in the bottom left corner is ~1.0 mm long.

Figure 5.44: Classification diagram for micas.

The contents of Rb and Cs in micas are low and in many cases the Cs content is close to the detection limit of the EMP (Fig. 5.45); however, the most fractionated pegmatites still exhibit elevated contents of Rb and Cs. The highest Rb and Cs contents were found in lepidolite from the LI2 pegmatite; elevated contents were found in muscovite from several localities (Fig. 5.46a & b). Biotite has a variable Fe/Mg ratio and F contents (0 to ~0.6 apfu F) and usually exhibits low Rb and Cs contents; the highest Rb and Cs content was found in the intermediate zone of the BERYL pegmatite.

A map of the elevated Rb contents (Fig. 5.46a) show a good match with the locations of the most fractionated pegmatites; a map of Cs contents only indicates the locations of the most highly fractionated pegmatites (Fig. 5.46b). The Rb map supports the potential significance of the SKINNY and TOURMUS pegmatites and confirms the elevated fractionation level of the GAR pegmatite (also indicated by the high Li, Be, and Mn contents and high X_{Fe} in sekaninaite).

Figure 5.45: Plot showing Rb₂O vs. Cs₂O for mica.

Figure 5.46a: Map showing elevated Rb content in mica.

Figure 5.46b: Map showing elevated Cs content in mica.

5.4 Garnet

Garnet was found in the BERYL, GAR, GARMUS, GARPPOS, GARTOUR, JAN, LI, LI2, LONG, SIMPLE14, TOURMUS, and WOBBLE pegmatites. In most cases, it forms dark red euhedral crystals within albite close to the center of the pegmatite. However, there are some exceptions: the garnet from the JAN pegmatite is light pink; late garnet veinlets in blocky quartz can be found in the BERYL pegmatite; replacing sekaninaite in the GAR pegmatite; quartz-garnet intergrowths can be found in the LI2 pegmatite; and garnets are sometimes associated with phosphate minerals in the GARPPOS pegmatite. Most garnet samples are spessartine, although almandine was found in the WOBBLE and GARTOUR pegmatites.

The garnet samples display high variation in the $\text{Mn}/(\text{Mn}+\text{Fe})$ ratio and very low contents of other elements typically found in garnet (Fig. 5.47). The highest Mn content was found in the JAN aplite (thin veinlet with slightly elevated Li in tourmaline) but otherwise the Mn content increases with increasing fractionation of the pegmatites (Fig. 5.48). Some of the highest contents were found in the elbaite pegmatite (GARPPOS) and spatially associated Be-rich pegmatites (TOURMUS and GAR); the lepidolite-bearing LI2 pegmatite has slightly lower Mn contents, especially in middle portion, intermediate between the lepidolite and phosphate-rich outcrops. The Ca and Mg contents decrease whereas both the Ti and P contents slightly increase with increasing Mn/Fe fractionation.

Figure 5.47: Plots showing the compositional variations of garnet within the study area.

Figure 5.48: Map showing where garnet samples had the greatest ratio of Mn/(Mn + Fe).

5.5 Cordierite Group

Minerals of the cordierite group (cordierite and sekaninaite) of different morphologies were found in the BERYL, CORD, GAR, JUNCT, SIMPLE9, and TOUR pegmatites in varying states of decomposition. Most frequently, they form euhedral crystals ~2 to 4 cm long, exceptionally up to 9 cm long (GAR; Fig. 3.8b). Cordierite from the TOUR pegmatite was found as cordierite-quartz intergrowth aggregates (Fig. 3.50b). The first euhedral form is frequent from cordierite-sekaninaite localities worldwide (e.g., Černý *et al.* 1997, Jobin-Bevans & Černý 1998, Povondra *et al.* 1984, Schreyer *et al.* 1979); the second form is rarely described, most descriptions are from migmatites and desilicated pegmatites (Černý & Povondra 1966, Černý *et al.* 1967).

Compositional data were collected only from the large crystal from the GAR pegmatite, as it was the freshest sample, only slightly altered along fractures into a mixture of muscovite, chlorite, secondary beryl, iron oxides, and minor biotite (Fig. 5.49). The analytical results indicate that the mineral is Mn,Mg-rich sekaninaite with high contents of Na (Fig. 5.50).

The contents of Al and (Fe + Mg + Mn) are lower than ideal values which, together with the Na content, indicates the presence of Li and Be; these were calculated using the procedure published by Bertoldi *et al.* 2004. The calculation shows the presence of significant Li up to ~0.3 apfu. However, the calculation results indicate randomly occurring elevated contents of Be (and locally negative values) which are positively correlated with Si and Al contents suggesting strong dependence on analytical precision and quality of the sample. The low Al and (Fe + Mg + Mn) contents show that the sample must be Li-bearing but it is not possible to precisely estimate Be using EMP data only – the presence of beryl as a secondary alteration product strongly suggests that the sekaninaite contains significant amounts of Be as well.

Figure 5.49: A BSE image of sekaninaite from the GAR pegmatite and its most common decomposition products.

Figure 5.50: Compositional diagram showing sekaninaite classification (left) and substitution schemes (right).

5.6 Beryl and Other Be-Minerals

5.6.1 Beryl

Primary beryl is typically subhedral, prismatic, translucent, and ranges in color from creamy white to pale blue. It is found in the BERYL, GARMUS, GARPPOS, GARTOUR, LI2 SIMPLE9, and TOURMUS pegmatites and tentatively identified in thin section from the SMALL pegmatite. One specimen collected from the BERYL pegmatite has a transparent yellow gemmy patch. In primary beryl-bearing localities, crystals are typically a few centimeters in size; crystals from the BERYL and LI2 dike can be much larger – the largest specimen collected from the BERYL pegmatite is 15 cm long and 10 cm wide, the largest beryl crystal collected from the LI2 is 9 cm long and 5 cm wide.

There are two types of secondary beryl: one is late stage beryl crystals that are acicular, typically forming overgrowths on larger beryl crystals and was only observed in the BERYL pegmatite; the other is microscopic beryl that is one of the products from the decomposition of cordierite. The latter type of secondary beryl was observed within the confines of the previous cordierite crystal from the BERYL, CORD, GAR, and SIMPLE9 pegmatites. The thin crystals of secondary beryl were identified using single-crystal X-ray diffraction and the microscopic beryl was identified using EDS and EMP analyses.

The beryl from the GARTOUR pegmatite is of uncertain origin and has not been analyzed. The only tiny grain (~400 μm long) identified was found enclosed in muscovite from a small pocket.

Most of the compositions of the beryl samples are displaced from the 1:1 line on a plot of the Al vs. the sum of other Y site cations (Mg + Mn + Fe; Fig. 5.52), suggesting some of the substitutions are occurring at the Z site in addition to the Y site. The slightly low Si content (~0.02 apfu less than the expected 6 apfu) and occasionally elevated (~0.02 apfu greater than the expected 6 apfu) needed to fill the Z site helps confirm this possibility (Brand *et al.* 2009).

The majority of the beryl crystals likely contain Fe^{3+} in addition to Fe^{2+} to maintain charge balance in the crystal, as most of the analyses plot below the 1:1 line for the sum of divalent cations vs. the sum of monovalent cations (Brand *et al.* 2009; Fig. 5.52). Likewise, beryl crystals from the BERYL, GARMUS, GARPPOS, and TOURMUS pegmatite appear to contain Li,

rather than Fe^{3+} to maintain charge balance in the crystal as those analyses plot above the 1:1 line.

Figure 5.52: Plots showing possible element substitution sites other than the Y site (left) and the sum of divalent cations vs. the sum of monovalent cations (right).

5.6.2 Other Be Minerals: Bertrandite, Chrysoberyl, and Euclase

Skeletal bertrandite was found in a white beryl crystal altering to plagioclase and clay minerals from the SIMPLE9 pegmatite (Fig. 5.53). EMP analyses show low contents of Al (~0.004 to 0.018 apfu Al) and Ca (~0.011 to 0.029 apfu Ca) present; this may be contamination from the plagioclase. Bertrandite is a relatively common alteration product after beryl (Černý 2002).

Figure 5.53: A BSE image of skeletal bertrandite (Brt) and plagioclase (Pl) after beryl (Brl) from the SIMPLE9 pegmatite. Bright gray spots are unidentified clay minerals.

Heavily fractured chrysoberyl was observed in the GARMUS pegmatite as inclusions in a fractured and partially recrystallized pale blue beryl crystal in contact with a slightly altered albite crystal (Fig. 5.54). EMP analyses show very low contents of Ti (~ 0.001 to ~ 0.004 apfu Ti) and somewhat elevated contents of Fe (~ 0.020 to ~ 0.035 apfu Fe). Chrysoberyl can be a primary magmatic Be phase in high temperature, low to moderately fractionated pegmatites or a metamorphic-metasomatic alteration product after beryl + albite + muscovite (Beurlen *et al.* 2013). Further investigation is needed to determine if this chrysoberyl occurrence is primary or secondary, as low-level alteration and fracturing is common across all mineral grains in this thin

section. Chrysoberyl has been tentatively identified in a thin section from the SMALL pegmatite using SEM only.

Fig. 5.54: Chrysoberyl (Cbl) in thin section under cross-polarized light as an inclusion in beryl (Brl) at the contact of an albite crystal (Ab). Field of view is 10 mm.

Euclase was identified using powder X-ray diffraction of the contents of a small “pocket” and cracks within a beryl crystal from the BERYL pegmatite. Other constituents of the “pocket” include garnet, muscovite, albite, and tourmaline (Fig. 5.55).

Figure 5.55: Photomicrograph of the constituent minerals in the “pocket” prior to removal for identification for powder X-ray diffraction. Black dashed line in the lower left corner of the image shows the length of 1 mm.

5.7 Oxides

5.7.1 Columbite-Tantalite

Minerals of the columbite-tantalite series were found in the BERYL, LI, LI2, GARMUS, SMALL and GARPHOS pegmatites.

In the BERYL pegmatite, columbite occurs in the intermediate zone and very near the core zone of the dike as inclusions in tourmaline and beryl and at tourmaline and beryl contacts. The samples have low and variable $X_{Ta} \sim 0.067$ to ~ 0.28 [$X_{Ta} = Ta / (Ta + Nb)$] and medium X_{Mn} (~ 0.36 to 0.53) on the ferrocolumbite-manganocolumbite boundary (Fig. 5.56). Columbite from the BERYL pegmatite contains up to 15.64 wt % WO_3 (0.265 apfu W^{6+}).

Figure 5.56: Diagram showing the classification and compositional trends of the columbite-tantalite specimens analyzed.

In the LI and LI2 pegmatites, columbite occurs in the intermediate and core zones in association with garnet, cleavelandite, and inclusions in tourmaline. The sample analyzed from the LI pegmatite grades from manganocolumbite to manganotantalite (Fig. 5.57); X_{Ta} varies from ~0.28 to ~0.72 and the X_{Mn} varies only slightly from ~0.65 to ~0.67 (Fig. 5.56). Manganocolumbite-manganotantalite from the LI pegmatite contains up to 2.81 wt. % WO_3 (0.012 apfu W^{6+}).

Figure 5.57: BSE image of manganocolumbite (Clb) grading into manganotantalite (Tnt) from the LI pegmatite.

In the GARMUS pegmatite, columbite occurs in the core zone in association with garnet. The sample appears homogeneous in BSE yet displays a distinct variation in its X_{Mn} values, with slightly over half ranging between ~ 0.47 and ~ 0.52 (mostly ferrocolumbite) and all others ranging between ~ 0.63 and 0.74 (manganocolumbite); the X_{Ta} values are only slightly variable, ranging between ~ 0.08 and ~ 0.11 (Fig. 5.56). The manganocolumbite X_{Mn} values come from analytical points near the rim of the crystal and U-rich inclusions. Only semi-quantitative data from the GARMUS ferrocolumbite-manganocolumbite and the W-rich manganocolumbite from the SMALL pegmatite sample were collected within the time constraints of this thesis.

In the GARPHOS pegmatite, columbite occurs in the intermediate zone in association with zircon, monazite, and triplite-zwieselite and in the core zone as inclusions in tourmaline. Intermediate zone samples have X_{Mn} values between ~ 0.60 and ~ 0.79 ; X_{Ta} values are between ~ 0.06 and ~ 0.16 . Core zone samples have X_{Mn} values between ~ 0.77 and ~ 0.99 ; X_{Ta} values are

between ~0.09 and ~0.39 (Fig. 5.56). Manganocolumbite from the GARPPOS pegmatite contains up to 17.01 wt. % WO_3 (0.277 apfu W^{6+}).

5.7.2 Rutile and Cassiterite

Rutile is observed to be in samples from the GARMUS, GARPPOS, GRANITE, JAN, LI, LI2, LONG, SIMPLE5, SIMPLE17, SMALL and SKINNY pegmatites. It was most frequently found in association with columbite and after biotite. It was analyzed in the GRANITE and GARPPOS pegmatites to examine the compositional differences that might be present between the most primitive pegmatite and one of the most fractionated pegmatites.

Rutile from the GRANITE pegmatite has up to of 2.21 wt. % Fe_2O_3 (0.023 apfu Fe^{3+}), 2.36 wt. % Nb_2O_5 (0.015 apfu Nb^{5+}), and 2.03 wt. % WO_3 (0.007 apfu W^{6+}). The rutile from the GARPPOS pegmatite has 11.08 wt. % Fe_2O_3 , and 19.14 wt. % Nb_2O_5 ; the formula is $\text{Ti}_{0.72}\text{Fe}_{0.12}\text{Nb}_{0.13}\text{O}_2$. The substitution mechanism for Fe and Nb into rutile is $\text{Fe}^{3+} + \text{Nb}^{5+}$ for 2Ti^{4+} .

Cassiterite was observed to be in samples from the BERYL, GARMUS and LI pegmatites. It was found in association with columbite from the BERYL pegmatite, a very small inclusion in a beryl crystal from the GARMUS pegmatite, and a very tiny inclusion in tourmaline from the LI pegmatite. It was analyzed in samples from the BERYL pegmatite because of its relatively larger sizes (up to 100 μm) and slightly greater frequency of occurrence. It has up to 4.99 wt. % Ta_2O_5 (0.034 apfu Ta^{5+}).

5.7.3 Wolframite Group and Bismutotantalite

Hübnerite, a species of the wolframite group, found in the GAR, GARPPOS, LI, and SMALL pegmatites, typically forms relatively large crystals (nearly 3 mm in length) compared to other oxide minerals encountered. In the GAR pegmatite, it is associated with muscovite and tourmaline replacing sekaninaite (Fig. 5.58). In the GARPPOS pegmatite, hübnerite was found in the intermediate zone associated with muscovite, spessartine, columbite, and triplite-zwieselite. Hübnerite was also observed in the core zone of the LI pegmatite associated with spessartine, muscovite, and tourmaline. Due to the time constraints of this thesis, hübnerite was analyzed only from the LI and GARPPOS pegmatites. Samples analyzed from the LI pegmatite contains up to 4.58 wt. % Nb_2O_5 (0.128 apfu Nb^{5+}) and 4.50 wt. % FeO (0.214 apfu Fe^{2+}).

Hübnerite from the GARPPOS pegmatite contains up to 6.59 wt. % Nb_2O_5 (0.179 apfu Nb^{5+}) and 15.94 wt. % FeO (0.535 apfu Fe^{2+}).

Bismutotantalite was observed as an inclusion in the fluor-elbaite rim of a Bi-containing green elbaite crystal in lepidolite from the core zone the LI2 pegmatite (Fig. 5.58). It was identified using EDS; its composition was not analyzed using EMP.

Figure 5.58: Left: Thin section through hübnerite (brown) with secondary muscovite (white) and tourmaline (blue) replacing sekaninaite in the GAR pegmatite; field of view is 4.2 mm. Right: BSE image of bismutotantalite (Btn) in the fluor-elbaite rim of a green elbaite (Elb) crystal partially surrounded by lepidolite (Lpd); white scale bar is 500 μm .

5.7.4 Qitianlingite

Qitianlingite, $(\text{Fe,Mn})_2(\text{Nb,Ta})_2\text{WO}_{10}$, was found in the BERYL, GARPPOS, and LI pegmatites in or very near the core zones of those pegmatites as zones within columbite in the BERYL pegmatite and zones within columbite inclusions in tourmaline from the GARPPOS and LI pegmatites (Fig. 5.59). In GARPPOS and BERYL is extremely rare and its composition is close to the ideal end-member formula (Fig. 5.60). The qitianlingite samples from LI have compositions close to the ideal end-member formula and part of the analytical data shows a transitional trend towards wolframite.

Minerals with W-rich compositions are frequently classified as wolframoixiolite (e.g. Alekseev *et al.* 2011). The good match of the Mount Begbie analytical data with the qitianlingite ideal end-member formula allowed their classification as qitianlingite, rather than the poorly defined (IMA-discredited) wolframoixiolite.

Figure 5.59: BSE image of a crystal with zones of qitianlingite and ferrocolumbite from the BERYL pegmatite.

Figure 5.60: Ternary diagram showing the classification of qitianlingite and other analyzed oxides.

5.7.5 Summary of Oxides

In general there is an extensive solid solution among the oxide minerals present. Rutile and cassiterite show a solid solution towards $\text{Fe}^{3+}(\text{Nb,Ta})\text{O}_4$ (Fe-analogue of heftetjernite). Hübnerite (wolframite group) shows a limited solid solution towards columbite. Columbite shows a solid solution towards rutile and towards wolframite. Qitianlingite lies on a solid solution line between columbite and wolframite; it exhibits variable contents of W and (Mn,Fe), representing a solid solution towards wolframite.

Rutile is an oxide common to many rock types and rutile with elevated Nb content is relatively common accessory mineral in pegmatites from around the world (e.g., rutile in lunar rocks, Marvin 1971; Borborema pegmatitic province in Brazil, Beurlen *et al.* 2007). Cassiterite is nearly as widespread as rutile but is restricted to environments associated with granites and granitic fluids (e.g., tin-mineralized topaz granites of the Qitianling tin district in China, Xie *et al.* 2013; Fregeneda-Almendra pegmatites at the Spain-Portugal border, Roda-Robles *et al.* 1999). Wolframite group minerals and W-rich columbite group minerals are common to medium- and low-T hydrothermal mineral deposits (e.g., the Sweet Home Mine in the Alma mining district, Colorado; Romer & Lüders 2006) and Li-rich rare metal granites and pegmatites (e.g., Beauvoir granite in France, Linnen 1998 and references therein; Glen Gairn granitic complex in Scotland, Tindle & Webb 1989; Bory pegmatite field in the Czech Republic, Novák *et al.* 2008). Bismutotantalite is a relatively rare mineral, associated only with highly evolved granitic pegmatites (e.g., La Elvirita granitic pegmatites in Argentina, Galliski *et al.* 2001). Qitianlingite is perhaps even more rare than bismutotantalite, being relatively recently described from a pegmatite in Qitianling, China (Anthony *et al.* 1997) and occasionally found in greisen environments (e.g. the Hensbarro topaz granite in Cornwall, Williamson *et al.* 1997; Breves Cu-Au-(W-Bi-Sn) deposit in Brazil, Tallarico *et al.* 2004).

5.8 Phosphates

5.8.1 Apatite

Apatite is an abundant mineral observed in samples from BERYL, CORD, GARMUS, GARPPOS, GRANITE, JUNCT, LI, LI2, SMALL, PEGMA, POCKET, TOUR, and TOURMUS pegmatites. Apatite is likely present in all other pegmatites but is difficult to discern

in the study area due to the fact it is typically fine grained, nearly colorless, and anhedral, giving it an appearance very similar to quartz. Apatite is more easily identified from the Mount Begbie pegmatites with the use of a shortwave UV light which causes it to fluoresce bright orange (Fig. 4.5).

Bright orange fluorescence could be caused by the presence of Mn^{2+} (Waychunas 2002) which is a common constituent in all apatite examined with SEM. Mn contents are greatest in the more fractionated pegmatites (LI, LI2, and GARPPOS) and elevated contents were found in BERYL, GARMUS, 12-GRANITE-S08, SMALL, TOUR, and TOURMUS (all using EDS only). EDS also revealed elevated levels of S in the moderately to more highly fractionated pegmatites (TOURMUS, LI, LI2, and GARPPOS).

Another common feature common to most apatite samples examined with the SEM is alteration. Grains can be heavily pitted, suggesting dissolution (Fig. 5.61). The elevated S content is somewhat correlated with the more altered apatite grains but may not be related to the alteration.

Figure 5.61: BSE image showing a typical example altered apatite from the LI pegmatite. Scale bar is 100 μm .

5.8.2 Mn, Fe - and Li -Phosphates

Mn, Fe-phosphates were found in as dark brown altered massive nodules in the GARPPOS, LI, LI2, and TOURMUS pegmatites. The most common Mn, Fe-phosphate encountered is triplite (Fig. 5.62); it was found in the GARPPOS, LI2, and TOURMUS pegmatites. In the lepidolite pegmatites (LI and LI2) small quantities of lithiophilite-triophyllite were found. Amblygonite was optically identified in a thin section from the core of the LI2 pegmatite. Results from powder X-ray diffraction suggest hureaulite and lipscombite may also be present in the LI2 and GARPPOS pegmatites as alteration products of triplite. The composition of the Fe,Mn- and Li-phosphates were not studied in detail.

Figure 5.62: A BSE image of triplite (Tp) rimmed by apatite (Ap) next to a perthite-like grain of K-feldspar (Kfs) and albite (Ab).

5.8.3 Monazite-(Ce) and Xenotime-(Y)

Monazite-(Ce) and xenotime-(Y) are very fine-grained, common REE-phosphate minerals in nearly all low to moderately fractionated pegmatite samples (BERYL, CORD, GARTOUR, GRANITE, PEGMA, SIMPLE, SIMPLE9, and SMALL) and locally in more highly fractionated pegmatites (GARPHOS); the presence of monazite and xenotime in the LI2 pegmatites is not confirmed. Monazite-(Ce) and xenotime-(Y) were analyzed in a primitive pegmatite (GRANITE), a moderately fractionated pegmatite (SIMPLE9), and highly fractionated pegmatite (GARPHOS) to determine if there are any significant compositional differences in the minerals between pegmatites.

Monazite fractionates light REE over middle and heavy REE; in comparison, xenotime preferentially incorporates middle and heavy REE (Hoshino *et al.* 2012, Masau *et al.* 2000). This same trend can be seen in the chondrite-normalized values for REE content analyzed in monazite and xenotime here (Fig. 5.63). Rare-earth elements heavier than Dy are below detection limits in monazite whereas in xenotime, REE heavier than Gd show slightly increasing contents.

In general, the chondrite-normalized values for the monazite-(Ce) samples from the GRANITE pegmatite show greater contents of REE than samples from the SIMPLE9 and GARPHOS pegmatites. Similarly, the SIMPLE9 pegmatite monazite-(Ce) displays greater contents of REE than those samples analyzed from the GARPHOS pegmatite. The opposite trend can be observed in the chondrite-normalized values for xenotime-(Y) samples; the SIMPLE9 pegmatite samples have an overall greater content of REE than samples from the GRANITE pegmatite.

Chondrite-normalized values for monazite-(Ce) samples from the GARPHOS pegmatite display a pattern similar to the lanthanide tetrad effect. The tetrad effect is common in highly fractionated granites and pegmatites (Irber 1999).

The analyzed monazite-(Ce) has relatively low contents of Ce (~0.268 to ~0.451 apfu) and relatively high contents of La (~0.041 to ~0.243 apfu), Nd (~0.087 to ~0.258 apfu), Sm (~0.031 to ~0.072 apfu), and locally elevated contents of Th (~0.019 to ~0.140 apfu). Slightly lower contents in Y (~0.687 to ~0.743 apfu Y) in the analyzed xenotime-(Y) are balanced by elevated contents of Dy (~0.042 to ~0.059 apfu Dy), Yb (~0.046 to ~0.076 apfu Yb) and locally abundant U (~0.002 to ~0.055 apfu U).

Where the content of Th is elevated in monazite, cheralite substitution ($2\text{REE}^{3+} \leftrightarrow (\text{Th,U})^{4+} + \text{Ca}^{2+}$) which is relatively common in monazite found in fractionated S-type granites (Hoshino *et al.* 2012), appears to be operating in the samples analyzed, as the ratio of Ca to Th+U is 1:1 (Fig. 5.63). Cheralite substitution occurs in monazite samples from the 12-GARPHOS-S04 sample site and one monazite sample from the 12-GRANITE-S05 sample site.

Figure 5.63: Left: Chondrite normalized values of REE in monazite and xenotime. Right: Points on the 1:1 line indicate cheralite substitution in monazite.

5.9 Andalusite, Petalite, and Topaz

Andalusite was observed in the central part of the CORD pegmatite (Fig. 3.5e) near its join with the JUNCT pegmatite and in the core zone of the GARMUS pegmatite. In both localities, the andalusite crystals are prismatic, pink, and up to ~5 cm long. Andalusite from the CORD pegmatite has dark blue inclusions and streaks; the inclusions resemble corundum typical for this assemblage from other localities (J. Cempírek, pers. commun.) but the inclusions here were identified as andalusite using EDS. It is unknown if the blue coloring is the result of unusual

zoning or perhaps a closely related aluminosilicate (kyanite or silimanite) resulting from events preceding or proceeding the crystallization of the andalusite.

Petalite from the LI pegmatite was positively identified using powder X-ray diffraction (Appendix B.1). Hand samples of petalite strongly resemble blocky albite; only careful scrutiny reveals the cleavage planes and rare crystal faces. Occasional patches in the petalite are nearly colorless and transparent. The presence of petalite in the LI pegmatite suggests the possibility other Li-minerals may be found there, such as spodumene and eucryptite – two of the possible breakdown products of petalite (Černý & London 1983).

Topaz was observed in thin sections from the core zone of the GARPPOS pegmatite and is associated with schorl-cored elbaite-rimmed tourmaline. Grains of topaz are subhedral and up to ~2 mm long. EMP analyses indicate the topaz is F-rich (~1.833 to ~2.000 apfu).

5.10 Allanite and Zircon

Allanite was observed as small grains (up to ~300 μm long) in fractures of feldspars next to slightly larger grains of tourmaline (up to ~500 μm in diameter) from the border zone of the LONG pegmatite (Fig. 5.64). It was identified using EDS.

Figure 5.64: A BSE image of allanite (Aln) from the LONG pegmatite.

Zircon is relatively abundant throughout the study area and forms tiny euhedral grains, usually not greater than ~50µm across; one zircon grain collected from the BERYL pegmatite is ~5 mm long and has a dark red-brown color. Zircon occurs throughout all pegmatite zones in association with a wide range of minerals and it is one of the most common inclusions in tourmaline. Zircons were observed in samples collected from the BERYL, CORD, GARMUS, GARPHOS, GRANITE, LENS2, LI, LI2, PEGMA, SIMPLE9, SMALL, and TOURMUS pegmatites using thin sections and SEM, and tentatively identified in thin sections from the SIMPLE12, SIMPLE16, SKINNY, and TOUR pegmatites.

Zircon grains were analyzed with EMP from the dikes which seemed to contain the greatest quantities of zircon (the BERYL, GARPHOS, GRANITE, LI³, PEGMA, SIMPLE9, and TOURMUS pegmatites). The Zr contents are slightly low (~0.861 to ~0.981 apfu) with slightly elevated Hf (~0.013 to 0.051 apfu) and locally elevated contents of U (up to ~0.141 apfu). As been shown as an indicator of fractionation (London 2008), the Hf content is slightly greater in the more fractionated pegmatites (Fig. 5.65).

Figure 5.65: Plot of Zr vs. Hf.

³ Unfortunately, analyses of the zircon grains from the LI pegmatite overlapped with tourmaline and were too altered to give meaningful results.

5.11 Sulfides

Occurrences of sulfide minerals within the study area are very uncommon. Most often, they are small (up to ~500 μm) Fe-sulfide inclusions in what appears to be primary iron oxides from pegmatites with low fractionation: the GRANITE, LONG, and SIMPLE11 pegmatites. One extremely tiny (~50 μm) Fe-sulfide crystal – tentatively identified as pyrrhotite using EDS – was observed in a sample of the BERYL pegmatite, apparently independent of iron oxides. Galena grains were observed as inclusions in a Fe-sulfide inclusion – tentatively identified as pyrite using EDS – in a crystal of primary iron oxide (Fig. 5.66).

Figure 5.66: A BSE image of galena inclusions in a Fe-sulfide inclusion in an Fe-oxide from the LONG pegmatite.

5.12 Chlorite Group and U-bearing Minerals

Chlorite group minerals are the most widespread secondary phase in the study area, occurring as alteration products after cordierite-sekaninaite and biotite. In most cases, alteration after biotite is limited to the border zones of pegmatites.

Small yellow crusts with black speckles and spheres of yellow acicular crystals of U-bearing minerals can occasionally be found coating the surface and small crevices in mineral

samples from the intermediate and core zones of the BERYL pegmatite. Uranophane (Fig. 5.67) has been identified from the BERYL pegmatite using powder XRD and EDS; phurcalite, rutherfordine, uraninite have been tentatively identified using the same techniques. Another phase of U + Ca silicate has also been found that appears to be somewhat compositionally different than uranophane; deeper investigation is needed to determine what it might be.

Grains of uraninite have been positively identified from the GARPHOS pegmatite using EDS; grains of autunite and uraninite have been tentatively identified using EDS on samples from the GARPHOS and LI pegmatites, respectively. Autunite and uraninite are associated with Fe,Mn-phosphates, columbite, monazite, xenotime and zircon; they are most often found as inclusions in zircon (Fig. 5.68).

Figure 5.67: Photomicrograph of uranophane from the BERYL pegmatite. Field of view is ~4 mm.

Figure 5.68: A BSE image of uraninite (Urn) inclusions in zircon (Zrn) with columbite (Clb) and monazite (Mnz) all as inclusions in triplite from the GARPHOS pegmatite.

Chapter 6: Discussion

6.1 Pegmatite Classification

Considering the pegmatites in this study as a whole, they belong to the rare-element class as defined by Černý & Ercit (2005). The majority of the pegmatites in the study area are barren with tourmaline, biotite, and locally occurring garnet as the main accessory phases. The BERYL, CORD, GAR, GARMUS, GARPPOS, GARTOUR, LI, LI2, SIMPLE9, SMALL, TOURMUS pegmatites all exhibit an evolved mineralogy that allows them to be classified as rare-element pegmatites (after Černý & Ercit 2005).

From a geochemical point of view, the mapped rare-element pegmatites show two distinct signatures. The BERYL pegmatite has mineralization that generally fits closer to the NYF family: absence of phosphates other than apatite, monazite, and xenotime; low fractionation of Nb/Ta as well as Fe/Mn in columbite; and presence of U mineralization. However, the presence of cassiterite and cordierite within the dike are uncommon for pegmatites of the NYF family and are more generally associated with pegmatites of the LCT family. It can be classified as a **beryl-columbite subtype** of beryl-type pegmatites.

The peraluminous Be-bearing pegmatites without other significant rare-element mineralization include the CORD, GARTOUR, and SIMPLE9 dikes. The presence of cordierite and muscovite seems to indicate they belong in the LCT family, rather than in the NYF family. Their classification is not possible based on the primitive mineral assemblages and are discussed here as **beryl-bearing pegmatites**. Similar but more fractionated are the GAR, GARMUS, and SMALL pegmatites. The presence of fractionated rare-metal oxides (hübnerite and/or manganocolumbite) is a clear geochemical signature of the LCT family. These pegmatites can be classified as **beryl-columbite subtype** pegmatites.

The beryl- and phosphate-bearing pegmatites with elbaite tourmaline located near the southeastern end of the GRANITE pegmatite (GARPPOS and TOURMUS) belong to the LCT family and can be classified either as Li-bearing beryl-columbite-phosphate subtype of beryl type pegmatites or as a phosphate-bearing elbaite subtype of complex type pegmatites. Neither the classifications fits the ideal geochemical signature as beryl-columbite-phosphate pegmatites are typically Li-poor and elbaite pegmatites are typically depleted in P and more rich in B (borates are characteristic of the subtype). Especially in the GARPPOS pegmatite, the mineral

assemblages in the two main sample sites differ significantly, making classification difficult; the more primitive part of the dike (12-GARPHOS-S04) has the mineral assemblage of beryl, Mn-Fe phosphates, columbite, and spessartine whereas the more fractionated part of the dike (12-GARPHOS-S01) has Mn-rich elbaite-rimmed tourmaline, topaz, spessartine and columbite. At the current knowledge of mineralization of both pegmatites, the former classification (**beryl-columbite-phosphate subtype**) seems to be more appropriate than the latter.

The most fractionated pegmatites, LI and LI2, belong to the LCT family, complex type of rare-element pegmatites, specifically the **lepidolite subtype**.

6.2 Mineral Fractionation Patterns

6.2.1 K-Feldspar and Micas

The analytical results from K-feldspar and micas clearly show the most fractionated pegmatites in maps of the Rb, Cs, and P concentrations (Fig. 5.42a, b, & c). Despite the fact that non-ideal analytical approach was available for this study (EMP instead of LA-ICP-MS), the combination of Rb, Cs, and P mark all rare-element pegmatites. The Cs in the K-feldspar map highlights the BERYL, GARMUS, GARPHOS, and LI2 pegmatites. The Rb in K-feldspar highlights the BERYL, GARPHOS, and LI2 pegmatites. The P in the K-feldspar highlights all the Mn-Fe phosphate-bearing pegmatites, the most fractionated pegmatites, and a few potential targets for further study. The Rb and Cs in micas unequivocally indicate the most fractionated rare-element pegmatites: BERYL, LI, and LI2; interestingly, the TOURMUS pegmatite shows greater fractionation in micas than the GARPHOS pegmatite. Less fractionated pegmatites only display slightly elevated concentrations of trace elements: SIMPLE9 (Rb in K-feldspar and micas), GAR (only Rb in micas), and SMALL (Rb and P in K-feldspar) pegmatites.

Possible higher fractionation is indicated in the SIMPLE13 (elevated Rb and Cs in K-feldspar), SKINNY (elevated Rb, Cs, and P in K-feldspar; Rb in mica), and POCKET (P in K-feldspar) pegmatites.

In general, the observed contents of Rb and Cs in both K-feldspar and micas throughout the study area are low compared to highly fractionated pegmatites (e.g., the Tanco pegmatite; Brown 2001) with the exception of the LI2 pegmatite. It is possible to conclude that EMP analysis of

K-feldspar and micas is a method that can be effectively used for detection of the most fractionated pegmatites, which are usually of most economic interest.

6.2.2 Garnet and Columbite

The degree of fractionation in garnet gives very similar results to the analyses of K-feldspar and micas. The garnets from pegmatites with low fractionation generally have an almandine composition with X_{Mn} below 0.5 (Fig. 5.48). All fractionated pegmatites contain spessartine with X_{Mn} between 0.55 and 0.8. The elevated X_{Mn} in the LONG pegmatite suggests that further study may yield more interesting mineralogical results. The highly anomalous garnet composition (almost pure spessartine) from the JAN aplite veinlets indicate that these may represent highly fractionated melt that escaped from a larger, fractionated pegmatite which is not exposed at the surface.

Columbite-group minerals only occur in the more fractionated rare-element pegmatites. The Mn/Fe ratio clearly marks the most evolved pegmatites whereas the Ta/Nb ratio typically increases during crystallization of the pegmatite from the intermediate to the core zones. The high Mn/Fe ratio of columbite in the SMALL pegmatite indicates it may be more highly fractionated than initially observed in the field (Fig. 6.1).

Compositional evolution of the columbite from BERYL closely resembles the trends seen from F-poor beryl-type pegmatites (Fig. 6.1). This agrees with the overall mineralogy of the BERYL pegmatite with minor apatite and only elevated F contents in tourmaline and micas. Likewise, evolution of columbite from the GARPHOS and LI pegmatites fits well to the trends observed in F-rich complex pegmatites. The high Mn/Fe ratios in GARMUS and SMALL suggest their higher fractionation and potentially elevated F contents.

Figure 6.1: Fractionation trends in columbite from Mount Begbie pegmatites (left) and general fractionation trends seen in columbite from complex and beryl pegmatites (right; modified after Černý 1989).

6.2.3 Tourmaline

Tourmaline from the LI and LI2 pegmatites exhibit very similar compositional evolution to the typical trends described for lepidolite-subtype pegmatites (“lepidolite pegmatites”) by Selway *et al.* (1999). During crystallization the Al/(Al+Fe) gradually increases from the most primitive to the most evolved tourmaline and show the typical trend (Fig. 6.2):

foitite → schorl → fluor-schorl → fluor-elbaite → rossmanite.

The trend observed for the LI and LI2 pegmatites for a plot of the Na vs. F is offset towards greater F in late tourmaline stages (fluor-elbaite and rossmanite) and is missing the very late Fe-enriched stages compared to the usual trend for lepidolite pegmatites (Fig. 6.2; Selway *et al.* 1999).

Figure 6.2: Tourmaline evolution trends from the LI and LI2 pegmatites (left; legend is same as Fig. 5.15a) and from lepidolite subtype-pegmatites (right; modified after Selway *et al.* 1999).

Tourmaline from the GARPPOS pegmatite exhibits a similar compositional evolution to the typical trends described for lepidolite pegmatites by Selway *et al.* (1999) but the evolution differs in several aspects (Fig. 6.3). The evolution of tourmaline for the GARPPOS pegmatite from border zone to core zone is:

Ca-rich dravite → Mg-rich schorl → Mg-rich schorl-foitite → schorl-foitite → (Fe,Mn)-elbaite → Mn-rich fluor-elbaite.

During tourmaline crystallization, the Al/(Al + Fe) ratio gradually increases for both GARPPOS and lepidolite pegmatites. The first difference is displayed by the composition of tourmaline in the border and wall zones, which is characterized by a transition from Ca-rich dravite to Mg-rich schorl accompanied with a rapid decrease in the Na/(Na + vacancy) ratio. The subsequent trend from Mg-rich schorl-foitite to (Fe,Mn)-elbaite is identical to the evolution of tourmaline in lepidolite pegmatites. The most evolved tourmaline is Mn-rich fluor-elbaite which does not farther evolve to Mn-poor rossmanite, contrary to the trend displayed by the lepidolite pegmatites. Late enrichment in Fe is common to both GARPPOS and lepidolite pegmatites. The gradual increase of Mn leading to its extreme enrichment and Fe-depletion in fluor-elbaite in the GARPPOS pegmatite is the most striking difference compared to the lepidolite pegmatites; the difference is well visible when comparing the tourmaline compositions of the LI, LI2 and GARPPOS pegmatites (Fig. 6.4). The extreme Mn-enrichment is typical for tourmaline in elbaite-subtype pegmatites (Novák & Povondra 1995). Like the trend observed for the LI and LI2 pegmatites, a plot of the Na vs. F for GARPPOS is offset, except in this case the offset is towards greater Na in early tourmaline stages (dravite and schorl).

Comparison of tourmaline evolution in all of the studied pegmatites where tourmaline was analyzed, shows differences among the Li-bearing pegmatites (the “Li-pegmatites”), pegmatites where Be is the main “rare element” (the “Be-pegmatites”), and primitive pegmatites (Fig. 6.5). In general, the compositional trends of the Be-pegmatites and the primitive pegmatites from Fe-rich dravite to Al-rich schorl overlap except the F contents of the most evolved samples from Be-pegmatites are elevated in comparison to those from primitive pegmatites. The border and wall zone tourmaline from the Li-pegmatites is similar to the Be-pegmatites, especially due to initial Mg-contamination of the melt from the host rock. All other tourmaline types from the Li-pegmatites display distinct Na-, Al-, Li-, and F-enrichment.

Figure 6.3: Tourmaline evolution trends from the GARCHOS pegmatite (left; legend is same as Fig. 5.7c) compared to tourmaline from lepidolite subtype-pegmatites (right; modified after Selway *et al.* 1999).

Figure 6.4: Comparison of the tourmaline evolution of the LI and LI2 (left) and GARCHOS pegmatites (right). Legends as mentioned above.

Figure 6.5: Comparison of all of compositional evolution of Li-, Be-, and primitive pegmatites.

6.3 Pegmatite Field Zoning

The pegmatites in the studied area generally follow two main strikes. The primitive pegmatites are generally subparallel to the GRANITE pegmatite (strike $\sim 290^\circ$) whereas the rare-element pegmatites are largely subparallel to the LI and LI2 pegmatites (strike $\sim 310^\circ$).

The distribution of beryl-bearing, beryl-columbite, beryl-columbite-phosphate, and lepidolite subtype pegmatites in the study area is irregular (Fig. 6.6). The most primitive beryl-bearing pegmatites (CORD and GARTOUR) are located in the southern part of the map area with the exception of the SIMPLE9 pegmatite is located more centrally.

Beryl-columbite pegmatites are either adjacent to the GRANITE pegmatite (SMALL and GAR) or along strike with the GAR pegmatite (GARMUS). The most important of the beryl-columbite pegmatites, BERYL, is isolated in the northern part of the study area.

The beryl-columbite-phosphate pegmatites (GARPHOS and TOURMUS) are adjacent to the GRANITE pegmatite and the most fractionated pegmatites which belong to the lepidolite subtype (LI and LI2) are on strike with them.

In general, the degree of pegmatite fractionation increases to the northwest, as indicated by the whole rock geochemistry from the GRANITE pegmatite. The strike from the southeast to the northwest of the most fractionated pegmatites (TOURMUS, GARPHOS, LI2, and LI) confirms this observation. The position of the source pluton is unknown but based on the zoning of the pegmatite field it is possible to speculate that it is located to the southeast of the study area at depth. The BERYL pegmatite may be part of a different system as it contains a unique mineralogy and has a dip (to the north) that opposes most of the dips of the other pegmatites (subvertical or to the south) or it could have originated during the same magmatic event through a different tectonic system.

Figure 6.6: Distribution of fractionated pegmatites.

6.4 Comparison to Other Pegmatite Fields

The Mount Begbie pegmatite field is rather unique within Canadian Cordillera and the Canadian Shield by the presence of lepidolite subtype pegmatites (cf. Černý 1990); it appears to have more commonalities with pegmatite fields elsewhere in the world.

The peraluminous and (Fe,Mn,P)-rich assemblage including andalusite, Fe,Mn-phosphate, W-rich oxides, and sekaninaite evolving to lepidolite subtype pegmatites is reminiscent of the Bory pegmatite district in the Czech Republic (e.g., Novák *et al* 2008).

The Bory pegmatite district comprises three types of granitic pegmatites with distinctly different degrees of fractionation, much like the trends observed at the Mount Begbie pegmatite field. The most abundant pegmatites in the Bory district are primitive, symmetrically zoned barren pegmatite dikes with schorl, muscovite, apatite, and local occurrences of andalusite and large crystals of sekaninaite. Less common are the more evolved, phosphate-bearing pegmatites characterized by the presence of primary Fe,Mn-phosphates (triplite, zwieselite, triphylite, graftonite, beusite); their mineral assemblages and internal structure indicate close affinity to the beryl-columbite-phosphate subtype. There are three pegmatites of the lepidolite-subtype within the whole district; they contain abundant elbaite, minor amblygonite-montebbrasite, cookeite and spodumene+quartz pseudomorphs after petalite. The greatest differences between the Mount Begbie pegmatite field and the Bory pegmatite district are the absence of beryl and common occurrence of ilmenite in the latter (Novák *et al* 2008).

Another pegmatite field similar to the one studied in this thesis are the pegmatites in the Fregeneda-Almendra pegmatite field of Spain and Portugal (Roda-Robles *et al.* 1999, Vieira *et al.* 2011). The Fregeneda-Almendra pegmatites show a zonal distribution, from barren to enrichment in Li, Sn, Rb, Nb > Ta, B and P. They display a zonal sequence from the Lumbrales granite outward: (1) barren pegmatites with quartz, K-feldspar > albite, muscovite, tourmaline +/- andalusite +/- garnet; (2) intermediate pegmatites characterized by the occurrence of beryl and Fe-Mn-Li phosphates; and (3) fertile pegmatites with lepidolite, cassiterite, columbite, albite > K-feldspar, montebbrasite and spodumene and quartz veins with albite and cassiterite. The field is similar to the Mount Begbie pegmatites by the degree of fractionation, high concentration of multiple dikes in a small area (Fig. 6.7), and mineralogy (beryl, Fe,Mn-phosphates, and lepidolite); the main differences include a higher fractionation degree of Ta/Nb in oxides, an

abundance of cassiterite and spodumene and a presence of Sn-bearing quartz-albite veins in the Fregeneda-Almendra pegmatites (Roda-Robles *et al.* 1999, Vieira *et al.* 2011).

Figure 6.7: Map of the Fregeneda-Almendra pegmatite field, modified after Vieira *et al.* (2011).

Several other pegmatite fields exhibit remarkable similarity with the beryl-columbite and beryl-columbite-phosphate pegmatites in the Mount Begbie pegmatite field. For example, Lahti (2000) described evolution of columbite group minerals from the Eräjärvi district in southern Finland which corresponds to that observed in this study; the similarity stems especially from a relatively high fractionation level in both pegmatite fields. Equivalent compositional trends were also described by Wise & Brown (2010) from the Sebago pegmatite group in southern Maine for the beryl, beryl-columbite, and beryl-columbite-phosphate pegmatites.

Chapter 7: Conclusions

Mapping the pegmatite field on the northern slope of Mount Begbie, near Revelstoke, B.C., revealed a dense population of pegmatites with diverse mineralogy and a relatively young, though uncertain, history. As the pegmatites are not strongly metamorphosed and show only rare foliation, it is improbable for them to have formed prior to the late Paleocene to Eocene exhumation and decompression event that exposed the Thor-Odin Culmination. However, they are more likely related to the other granitic bodies resulting from the exhumation event (the abundant migmatites and the Ladybird granite suite) than any other known intrusion.

In general, the pegmatites in the study area are elongate, with most having length of at least 10 m and not being more than one meter wide. Nearly all strike between 295° and 330° and have a subvertical dip; these orientations are somewhat dictated by weakened planes in the host rock caused by shearing during the exhumation and decompression event.

Many pegmatites exhibit subtle zoning with coarser cores than their finer grained border zones; intermediate and core zones usually display increasing fractionation. The most primitive mineral assemblages observed in the pegmatites are quartz + feldspar + black tourmaline or quartz + feldspar + biotite. Intermediate assemblages (corresponding to beryl-bearing and beryl-columbite subtype pegmatites) add muscovite, garnet, beryl, cordierite, and HFSE-oxides to the basic assemblage. Highly fractionated assemblages (corresponding with the beryl-columbite-phosphate and lepidolite subtype pegmatites) contain all of these features as well as phosphates other than apatite, monazite, and xenotime, lepidolite, petalite, and multi-colored tourmaline.

Geochemically, the pegmatites – including the most primitive GRANITE pegmatite – fractionate in a manner consistent with S-type granites. Fractionation variability within individual pegmatites (particularly the more primitive ones) could be controlled either by localized fluid accumulation or the composition of the original source rock. Despite being variable, fractionation for the pegmatite field increases from the southeast to the northwest. This suggests the source pluton may be located to the southeast of the study area at depth.

Maps of elevated Cs and Rb concentrations in K-feldspar and micas, P concentrations in K-feldspar, and the X_{Mn} value in garnet match the fractionation trend observed in the field and confirm the elevated fractionation of the GAR and TOURMUS pegmatites (which appear to be relatively primitive looking in the field). These maps also suggest the LENS, PEGMA,

SIMPLE13, and SKINNY pegmatites as well as the JAN aplites are worth greater investigation in the future.

The results of the detailed study of the minerals tourmaline, cordierite, beryl, oxides, and zircon as well as the mainly qualitative study of phosphates and other minerals agree with the trace element concentration maps and the garnet X_{Mn} value map mentioned above. They also provide insight to the geochemistry and mineralogy of the individual dikes. In particular, the results suggest the GARMUS and SMALL pegmatites may provide interesting future studies and highlight the BERYL and GARPPOS pegmatites as being unusual for the typical description of beryl-columbite and beryl-columbite-phosphate subtype pegmatites, respectively.

Additionally, the elevated contents of Be and Li in sekaninaite and the presence of qitianlingite in the Mount Begbie pegmatite field are somewhat unique in comparison to other cordierite and rare-element oxide localities worldwide. This pegmatite field represents one of three known Li-rich pegmatite fields in the Canadian Cordillera, with the Little Nahanni and O'Grady Batholith pegmatite fields being the other two.

7.1 Economic Potential

As one of a few, relatively well known, Li-rich pegmatite fields in the Canadian Cordillera, the Mount Begbie pegmatites have already provided excellent specimens for enterprising prospectors and miners conducting small-scale mineral and gem collecting. The potential for rare-metal mining operations may also exist in the pegmatite field.

The greatest rare-metal mining potential may lie with the BERYL pegmatite. Beryl mineralization is much more extensive in the BERYL pegmatite than in any other part of the study area. As can be seen in Fig. 3.3a, the BERYL pegmatite is significantly wider at the bottom of the outcrop than at the top. This suggests the dike is larger at depth; beryl mineralization in the dike beyond the exposed outcrop is likely to continue as well.

Another rare-metal mining potential exists in W-rich-oxides. Although crystals of W-rich oxides are not as immediately noticeable as beryl crystals, their presence is nearly as widespread as beryl in the pegmatite field. The minerals hübnerite, qitianlingite, W-rich columbite, cassiterite, and topaz distributed throughout the Mount Begbie pegmatites are also associated with W-Sn deposits worldwide (cf. Xie *et al.* 2013, Roda-Robles *et al.* 1999, Romer & Lüders 2006, Tindle & Webb 1989, Williamson *et al.* 1997, Tallarico *et al.* 2004).

Chapter 8: Suggestions for Future Work

Future work on the Mount Begbie pegmatite field should include completing mapping and sampling the southern part of the study area. Mapping beyond the confines of the area within this study is likely to reveal additional highly fractionated pegmatites on Mount Begbie and elsewhere within the Thor-Odin Culmination (H. Hyder & L. Addie, pers. commun.).

Analyses of tourmaline and trace minerals from the SKINNY and SMALL pegmatites were not fully completed within the time constraints of this study. Furthermore, in-depth investigations of the BERYL, GAR, GARPPOS, JAN, LENS, PEGMA, SIMPLE13, and TOURMUS pegmatites would create a completely comprehensive data set. With regards to the BERYL and GARPPOS pegmatite, this will help clarify their classification. It may even reveal links between the NYF and LCT pegmatite families (BERYL) and beryl-columbite-phosphate and elbaite-subtype pegmatites (GARPPOS). Lastly, the resulting dataset may even assist in determining the economic potential of pegmatite field.

Additionally, detailed studies on the primary and secondary phosphate minerals will help to further delineate the geochemistry of individual pegmatites; this may also be able to confirm the exact relationship between the LI and LI2 pegmatites. Similarly, meticulous examination of the cordierite-sekaninaite mineralization with LA-ICP-MS or SIMS to investigate the apparently elevated contents of Be and Li will further the geochemical understanding of individual cordierite-bearing dikes. It will even afford an opportunity to investigate the role of Li and Be within the sekaninaite-cordierite mineral series.

Boron isotope studies on Mount Begbie using data from the host rocks and the pegmatites would give a clearer picture of the origin of the pegmatite melt. $^{40}\text{Ar}/^{39}\text{Ar}$ dating should be completed on muscovite samples from various locations within the pegmatite field; along with the isotope study this will help to confirm the crystallization of the pegmatites within the context of the exhumation and decompression event. The results of a geochronology study may reveal separate pegmatite systems, explaining the widely ranging fractionation patterns observed. Together, both studies should be able to clarify the relationship of the pegmatites to the host rock, Ladybird granite suite, or a yet unknown pluton.

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Appendices

A.1 Mount Begbie Pegmatites

Pegmatite Outcrop

- Pegmatites with Approximate Orientations
- ≤ 1 m wide
- 1 to ≤ 5 m wide
- > 5 m wide

Regional Geology

- E_{tvi} Eocene kersantite lamprophyre dike (Kruse 2006).
- D_E Exhumation-related shear band (Kruse 2006, Kruse 2007).
- P_{ps} Pelitic and semi-pelitic schists and gneisses: Generally rich in aluminosilicates and garnet. May contain lenses of quartzite, calc-silicate and amphibolite (Kruse *et al.* 2005).
- P_{cs} Calc-silicate gneiss: May contain lenses and layers of pelitic schist, quartzite, amphibole and marble (Kruse *et al.* 2005).
- P_q Basal quartzite: Variable amount of feldspar grading into gneiss; may contain lenses of schist, paragneiss, and amphibolite (Kruse *et al.* 2005).

Geographical Features

- Previous Glacial Extent
- Rivers
- Lakes

Elevation

- 40 m contours
- 200 m contours

A.2 Mount Begbie Pegmatites

◆ Sample Site

Pegmatite Outcrop

- Pegmatites with Approximate Orientations
- ≤ 1 m wide
- 1 to ≤ 5 m wide
- > 5 m wide

Regional Geology

- E_{tv} Eocene kersantite lamprophyre dike (Kruse 2006).
- D_E Exhumation-related shear band (Kruse 2006, Kruse 2007).
- P_{ps} Pelitic and semi-pelitic schists and gneisses: Generally rich in aluminosilicates and garnet. May contain lenses of quartzite, calc-silicate and amphibolite (Kruse *et al.* 2005).
- P_{cs} Calc-silicate gneiss: May contain lenses and layers of pelitic schist, quartzite, amphibole and marble (Kruse *et al.* 2005).
- P_q Basal quartzite: Variable amount of feldspar grading into gneiss; may contain lenses of schist, paragneiss, and amphibolite (Kruse *et al.* 2005).

Geographical Features

- Previous Glacial Extent
- Rivers
- Lakes

Elevation

- 40 m contours
- 200 m contours

A.3 All Pegmatite Coordinates and Sample Sites

ALL PEGMATITE COORDINATES AND SAMPLE SITES (UTM, WGS 84)

Pegmatite	Point Name	Zone	Easting	Northing	Elevation
BERYL	12-BERYL-E	11	412325	5639256	2078
	12-BERYL-M01	11	412320	5639261	2067
	12-BERYL-M02	11	412316	5639264	2066
	12-BERYL-PEG	11	412299	5639274	2058
	12-BERYL-S01*	11	412314	5639266	2067
	12-BERYL-S02*	11	412321	5639255	2066
	12-BERYL-S03*	11	412323	5639255	2064
	12-BERYL-S04*	11	412306	5639273	2069
	12-BERYL-S05*	11	412301	5639280	2066
	12-BERYL-W	11	412292	5639283	2065
BITOUR	12-BITOUR-E	11	412282	5638962	2123
	12-BITOUR-M01	11	412276	5638968	2121
	12-BITOUR-M02	11	412270	5638970	2122
	12-BITOUR-W	11	412260	5638969	2123
CORD	12-CORD-M01	11	412397	5638533	2189
	12-CORD-M02	11	412392	5638537	2187
	12-CORD-M03	11	412391	5638540	2186
	12-CORD-M04	11	412392	5638550	2188
	12-CORD-M05	11	412389	5638558	2187
	12-CORD-M06	11	412389	5638562	2186
	12-CORD-N	11	412381	5638575	2183
	12-CORD-S	11	412400	5638528	2189
	12-CORD-S01*	11	412390	5638559	2184
	12-CORD-S02*	11	412390	5638559	2184
	12-CORD-S03*	11	412389	5638562	2184
	12-CORD-S04*	11	412379	5638577	2182
	12-ACT-PEG	11	412400	5638525	2190
	12-CRACK-PEG	11	412399	5638526	2190
CORNER	12-CORNER-M01	11	412287	5638923	2132
	12-CORNER-M02	11	412280	5638931	2134
	12-CORNER-M03	11	412279	5638930	2134
	12-CORNER-M04	11	412275	5638932	2134
	12-CORNER-N	11	412276	5638936	2133
	12-LONG-J02	11	412284	5638917	2136

* Denotes sites where samples were taken

ALL PEGMATITE COORDINATES AND SAMPLE SITES (UTM, WGS 84) CONT'D

Pegmatite	Point Name	Zone	Easting	Northing	Elevation
FEED	12-FEED-N	11	412380	5638905	2127
	12-FEED-PEG	11	412380	5638896	2127
	12-FEED-S	11	412375	5638891	2128
GAR	12-GAR-M01	11	412472	5638772	2114
	12-GAR-M02	11	412466	5638775	2115
	12-GAR-M04	11	412441	5638800	2112
	12-GAR-M05	11	412437	5638802	2113
	12-GAR-PEG	11	412473	5638773	2116
	12-GAR-S01*	11	412475	5638769	2119
	12-GAR-S02*	11	412434	5638803	2116
	12-GAR-S03*	11	412460	5638781	2118
	12-GAR-W	11	412401	5638828	2118
	12-GRANIT-SP02	11	412480	5638758	2118
GARMUS	12-GARMUS-N1	11	412403	5638900	2129
	12-GARMUS-N2	11	412399	5638895	2131
	12-GARMUS-N3	11	412390	5638897	2126
	12-GARMUS-S	11	412419	5638866	2128
	12-GARMUS-S01*	11	412398	5638883	2123
	12-GARMUS-SP01	11	412396	5638885	2130
GARPPOS	12-GARPPOS-E	11	412606	5638722	2113
	12-GARPPOS-S01*	11	412570	5638748	2115
	12-GARPPOS-S02*	11	412571	5638748	2111
	12-GARPPOS-S03*	11	412570	5638748	2111
	12-GARPPOS-S04*	11	412583	5638741	2111
	12-GARPPOS-W	11	412568	5638752	2118
GARTOUR	12-GARTOUR-M01	11	412470	5638489	2188
	12-GARTOUR-M02	11	412473	5638486	2189
	12-GARTOUR-M03	11	412477	5638482	2188
	12-GARTOUR-M04	11	412480	5638479	2189
	12-GARTOUR-N	11	412463	5638501	2190
	12-GARTOUR-PEG	11	412476	5638485	2184
	12-GARTOUR-S01*	11	412476	5638485	2184
	12-GARTOUR-S	11	412487	5638469	2191
GRANITE	12-GRANIT-SP01	11	412552	5638744	2121
	12-GRANIT-SP02	11	412480	5638758	2118
	12-GRANIT-SP03	11	412560	5638742	2121

* Denotes sites where samples were taken

ALL PEGMATITE COORDINATES AND SAMPLE SITES (UTM, WGS 84) CONT'D

Pegmatite	Point Name	Zone	Easting	Northing	Elevation
GRANITE (cont'd)	12-GRANITE	11	412363	5638803	2134
	12-GRANITE-E	11	412650	5638711	2109
	12-GRANITE-M01	11	412526	5638732	2119
	12-GRANITE-M02	11	412468	5638754	2118
	12-GRANITE-M03	11	412454	5638761	2121
	12-GRANITE-M04	11	412354	5638808	2133
	12-GRANITE-M05	11	412345	5638814	2134
	12-GRANITE-M06	11	412336	5638812	2135
	12-GRANITE-M07	11	412331	5638812	2136
	12-GRANITE-M08	11	412321	5638820	2138
	12-GRANITE-M09	11	412300	5638833	2142
	12-GRANITE-M10	11	412297	5638839	2148
	12-GRANITE-M11	11	412286	5638842	2149
	12-GRANITE-M12	11	412277	5638847	2149
	12-GRANITE-M13	11	412274	5638851	2148
	12-GRANITE-M14	11	412255	5638857	2149
	12-GRANITE-M15	11	412174	5638889	2144
	12-GRANITE-S01*	11	412649	5638709	2108
	12-GRANITE-S02*	11	412558	5638740	2121
	12-GRANITE-S03*	11	412524	5638746	2119
	12-GRANITE-S04*	11	412472	5638756	2115
	12-GRANITE-S05*	11	412619	5638714	2111
	12-GRANITE-S06*	11	412403	5638783	2131
	12-GRANITE-S07*	11	412345	5638814	2134
	12-GRANITE-S08*	11	412300	5638833	2142
	12-GRANITE-S09*	11	412229	5638867	2146
	12-GARPHOS-E	11	412606	5638722	2113
	12-KINK-PEG	11	412276	5638850	2152
	12-SIMP11-J01	11	412508	5638751	2119
JAN	12-JAN-S01	11	412065	5638940	2152
JUNCT	12-JUNCT-E	11	412430	5638580	2182
	12-JUNCT-M01	11	412358	5638575	2182
	12-JUNCT-M02	11	412362	5638576	2182
	12-JUNCT-M03	11	412368	5638576	2183
	12-JUNCT-PEG	11	412379	5638577	2181
	12-JUNCT-S01*	11	412375	5638575	2185

* Denotes sites where samples were taken

ALL PEGMATITE COORDINATES AND SAMPLE SITES (UTM, WGS 84) CONT'D

Pegmatite	Point Name	Zone	Easting	Northing	Elevation
JUNCT (cont'd)	12-JUNCT-S02**	11	412414	5638572	2186
	12-JUNCT-S	11	412418	5638563	2186
	12-JUNCT-SP01	11	412375	5638575	2185
	12-JUNCT-SP03	11	412392	5638576	2183
	12-JUNCT-SP04	11	412411	5638579	2183
	12-JUNCT-W	11	412355	5638575	2182
	12-JUNCT-W1	11	412373	5638578	2183
	12-JUNCT-W2	11	412392	5638583	2184
LENS	12-LENS-S01*	11	412298	5638697	2185
LENS2	12-LENS2-S01*	11	412466	5638556	2182
LI	12-LI-E	11	412399	5638927	2120
	12-LI-E1	11	412366	5638960	2119
	12-LI-E2	11	412365	5638959	2120
	12-LI-J01	11	412366	5638963	2116
	12-LI-J02	11	412355	5638972	2113
	12-LI-M01	11	412348	5638963	2117
	12-LI-M02	11	412357	5638925	2119
	12-LI-M03	11	412359	5638959	2116
	12-LI-M04	11	412362	5638965	2114
	12-LI-M05	11	412355	5638967	2116
	12-LI-M06	11	412357	5638970	2115
	12-LI-PEG	11	412350	5638969	2112
	12-LI-S	11	412348	5638961	2118
	12-LI-S01*	11	412349	5638969	2115
	12-LI-S1	11	412344	5638960	2117
	12-LI-S2	11	412347	5638959	2117
	12-LI-SP01	11	412347	5638964	2116
	12-LI-SP02	11	412349	5638962	2117
	12-LI-W	11	412342	5638969	2115
	12-LI-W1	11	412341	5638966	2115
	12-LI-W2	11	412340	5638963	2116
	12-LI-W3	11	412341	5638982	2111
	12-LI-W4	11	412343	5638975	2114

* Denotes sites where samples were taken

** Sample taken and site coordinates estimated

ALL PEGMATITE COORDINATES AND SAMPLE SITES (UTM, WGS 84) CONT'D

Pegmatite	Point Name	Zone	Easting	Northing	Elevation
LI2	12-LI2-E	11	412478	5638841	2114
	12-LI2-J01	11	412432	5638896	2117
	12-LI2-J02	11	412432	5638895	2124
	12-LI2-M01	11	412377	5638952	2115
	12-LI2-M02	11	412440	5638883	2125
	12-LI2-M03	11	412444	5638893	2125
	12-LI2-M04	11	412437	5638873	2130
	12-LI2-PEG	11	412460	5638855	2115
	12-LI2-S01*	11	412460	5638855	2115
	12-LI2-S02*	11	412464	5638860	2116
	12-LI2-S03*	11	412409	5638919	2117
	12-LI2-S04*	11	412431	5638877	2125
	12-LI2-SP01	11	412425	5638886	2117
	12-LI2-SP01-W	11	412396	5638901	2116
	12-CREEK-PEG	11	412404	5638919	2115
LONG	12-LONG-E	11	412333	5638896	2135
	12-LONG-J01	11	412209	5638940	2135
	12-LONG-J02	11	412284	5638917	2136
	12-LONG-M01	11	412264	5638924	2140
	12-LONG-M02	11	412154	5638962	2140
	12-LONG-M03	11	412163	5638960	2140
	12-LONG-M04	11	412182	5638951	2139
	12-LONG-M05	11	412136	5638968	2142
	12-LONG-S01*	11	412223	5638942	2135
	12-LONG-SP01	11	412239	5638939	2139
	12-LONG-W	11	412127	5638968	2144
META	12-META-BDF	11	412239	5638958	2129
	12-META-E	11	412279	5638941	2132
	12-META-THICK	11	412212	5638972	2128
	12-META-V	11	412217	5638966	2127
	12-META-W	11	412257	5638951	2132
	12-META-W1	11	412172	5639004	2134
MORE	12-MORE-PEGS	11	412487	5638447	2195
MUSC	12-MUSC-E	11	412211	5638870	2154
	12-MUSC-M01	11	412202	5638872	2155
	12-MUSC-S01*	11	412163	5638883	2156
	12-MUSC-W	11	412159	5638885	2156

* Denotes sites where samples were taken

ALL PEGMATITE COORDINATES AND SAMPLE SITES (UTM, WGS 84) CONT'D

Pegmatite Point Name		Zone	Easting	Northing	Elevation
ODD	12-ODD-PEG	11	412403	5639098	2110
PEGMA	12-PEGMA-E	11	412281	5638958	2124
	12-PEGMA-J01	11	412260	5638970	2126
	12-PEGMA-M01	11	412272	5638962	2126
	12-PEGMA-M02	11	412275	5638952	2128
	12-PEGMA-M03	11	412268	5638957	2127
	12-PEGMA-M04	11	412259	5638964	2128
	12-PEGMA-S01*	11	412254	5638978	2125
	12-PEGMA-S02*	11	412235	5638989	2122
	12-PEGMA-SP01	11	412279	5638959	2125
	12-PEGMA-W	11	412235	5638989	2122
POCKET	12-POCKET-N	11	412258	5638689	2195
	12-POCKET-S	11	412260	5638688	2195
	12-POCKET-S01*	11	412258	5638685	2196
QTZ	12-QTZ-E	11	412292	5638708	2189
	12-QTZ-M01	11	412283	5638711	2189
	12-QTZ-M02	11	412277	5638721	2190
	12-QTZ-W	11	412274	5638728	2189
QTZ2	12-QTZ2-E	11	412295	5638715	2187
	12-QTZ2-M01	11	412288	5638723	2186
	12-QTZ2-W	11	412282	5638729	2185
QTZ3	12-QTZ3-E	11	412294	5638712	2184
	12-QTZ3-E1	11	412273	5638725	2184
	12-QTZ3-E2	11	412316	5638734	2179
	12-QTZ3-M01	11	412288	5638724	2184
	12-QTZ3-M02	11	412281	5638728	2182
	12-QTZ3-M03	11	412291	5638733	2181
	12-QTZ3-M04	11	412297	5638736	2179
	12-QTZ3-SP01	11	412285	5638726	2183
	12-QTZ3-SP02	11	412269	5638729	2184
	12-QTZ3-W	11	412262	5638728	2184
SCABBY	12-SCABBY-E	11	412180	5638958	2140
	12-SCABBY-W	11	412049	5639014	2146
SIMPLE	12-SIMPLE-E	11	412506	5638837	2103
	12-SIMPLE-PEG	11	412490	5638869	2113

* Denotes sites where samples were taken

ALL PEGMATITE COORDINATES AND SAMPLE SITES (UTM, WGS 84) CONT'D

Pegmatite	Point Name	Zone	Easting	Northing	Elevation
SIMPLE (cont'd)	12-SIMPLE-S01*	11	412495	5638850	2110
	12-SIMPLE-S02*	11	412496	5638846	2107
	12-SIMPLE-W	11	412488	5638896	2110
SIMPLE2	12-SIMPLE2-N	11	412537	5638845	2107
	12-SIMPLE2-PEG	11	412537	5638844	2108
	12-SIMPLE2-S	11	412533	5638842	2108
	12-SIMPLE2-S01*	11	412533	5638843	2106
SIMPLE3	12-SIMPLE3-N	11	412557	5638843	2108
	12-SIMPLE3-S	11	412562	5638833	2106
	12-SIMPLE3-S01*	11	412559	5638836	2107
SIMPLE4	12-SIMPLE4-N	11	412565	5638847	2109
	12-SIMPLE4-S	11	412578	5638829	2106
	12-SIMPLE4-S01*	11	412576	5638828	2106
SIMPLE5	12-SIMPLE5-E	11	412633	5638821	2106
	12-SIMPLE5-N	11	412572	5638847	2107
	12-SIMPLE5-S	11	412599	5638824	2108
	12-SIMPLE5-S01*	11	412587	5638832	2106
SIMPLE6	12-SIMPLE6-E1	11	412386	5638884	2130
	12-SIMPLE6-E2	11	412386	5638888	2128
	12-SIMPLE6-E3	11	412366	5638891	2127
	12-SIMPLE6-E4	11	412366	5638909	2122
	12-SIMPLE6-J01	11	412373	5638890	2125
	12-SIMPLE6-J02	11	412362	5638896	2128
	12-SIMPLE6-J03	11	412361	5638913	2119
	12-SIMPLE6-W	11	412339	5638958	2113
	12-SIMP6-S01*	11	412352	5638937	2117
SIMPLE7	12-SIMPLE7-N	11	412346	5638912	2127
	12-SIMPLE7-S	11	412347	5638901	2130
	12-SIMP7-S01*	11	412347	5638909	2128
SIMPLE8	12-SIMPLE8-E	11	412404	5638519	2191
	12-SIMPLE8-PEG	11	412400	5638519	2190
	12-SIMPLE8-W	11	412393	5638520	2190
SIMPLE9	12-SIMPLE9-B	11	412305	5638927	2131
	12-SIMPLE9-B1	11	412288	5638985	2114
	12-SIMPLE9-E	11	412338	5638901	2132

* Denotes sites where samples were taken

ALL PEGMATITE COORDINATES AND SAMPLE SITES (UTM, WGS 84) CONT'D

Pegmatite	Point Name	Zone	Easting	Northing	Elevation
SIMPLE9 (cont'd)	12-SIMPLE9-E2	11	412327	5638907	2132
	12-SIMPLE9-W2	11	412302	5638920	2132
	12-SIMPLE9-X	11	412299	5638934	2126
	12-SIMP9-M01	11	412323	5638911	2131
	12-SIMP9-M02	11	412268	5639010	2112
	12-SIMP9-M03	11	412256	5639026	2112
	12-SIMP9-M04	11	412243	5639041	2112
	12-SIMP9-M05	11	412237	5639043	2113
	12-SIMP9-M06	11	412215	5639064	2115
	12-SIMP9-M07	11	412194	5639078	2117
	12-SIMP9-M08	11	412190	5639086	2116
	12-SIMP9-S01	11	412307	5638917	2133
	12-SIMP9-S02	11	412315	5638923	2130
	12-SIMP9-S03	11	412312	5638924	2131
	12-SIMPLE9-S04*	11	412311	5638919	2126
	12-SIMPLE9-S05*	11	412310	5638914	2130
	12-SIMP9-SP01	11	412325	5638914	2128
	12-SIMPLE-W1	11	412186	5639091	2115
SIMPLE10	12-SIMP-10	11	412388	5639114	2093
	12-SIMP10-W	11	412367	5639127	2095
SIMPLE11	12-SIMP11-E	11	412526	5638742	2120
	12-SIMP11-J01	11	412508	5638751	2119
	12-SIMPLE11-S01*	11	412524	5638745	2120
SIMPLE12	12-SIMP12-E	11	412165	5638813	2179
	12-SIMP12-J01	11	412064	5638899	2171
	12-SIMP12-M01	11	412108	5638863	2175
	12-SIMP12-M02	11	412120	5638850	2175
	12-SIMP12-M03	11	412125	5638843	2176
	12-SIMPLE12-S01*	11	412064	5638899	2171
	12-SIMPLE12-S02*	11	412133	5638836	2176
	12-SIMP12-W	11	412047	5638906	2168
	12-SIMP12-W1	11	412045	5638910	2167
SIMPLE13	12-SIMP13-E	11	412099	5638854	2178
	12-SIMP13-M01	11	412058	5638881	2178
	12-SIMP13-M02	11	412073	5638872	2179
	12-SIMPLE13-S01*	11	412036	5638890	2175
	12-SIMP13-W	11	412029	5638894	2176

* Denotes sites where samples were taken

ALL PEGMATITE COORDINATES AND SAMPLE SITES (UTM, WGS 84) CONT'D

Pegmatite	Point Name	Zone	Easting	Northing	Elevation
SIMPLE14	12-SIMP14-E	11	412121	5638789	2191
	12-SIMP14-E1	11	412120	5638790	2192
	12-SIMP14-J01	11	412119	5638791	2192
	12-SIMP14-M01	11	412111	5638793	2192
	12-SIMP14-M02	11	412109	5638794	2192
	12-SIMP14-M03	11	412105	5638796	2193
	12-SIMP14-M04	11	412102	5638796	2193
	12-SIMPLE14-S01*	11	412097	5638794	2195
	12-SIMP14-W	11	412097	5638794	2194
SIMPLE15	12-SIMPLE15-S01*	11	412319	5638639	2185
SIMPLE16	12-SIMP16-E	11	412303	5638577	2184
	12-SIMP16-M01	11	412291	5638581	2189
	12-SIMP16-M02	11	412285	5638580	2189
	12-SIMP16-M03	11	412279	5638581	2190
	12-SIMP16-M04	11	412268	5638580	2191
	12-SIMPLE16-S01*	11	412291	5638582	2190
	12-SIMPLE16-S02*	11	412287	5638578	2191
	12-SIMP16-SP01	11	412294	5638582	2188
	12-SIMP16-W	11	412263	5638580	2191
	12-SIMP16-W1	11	412291	5638582	2190
SIMPLE17	12-SIMP17-E	11	412334	5638531	2187
	12-SIMP17-M01	11	412330	5638533	2189
	12-SIMPLE17-S01*	11	412332	5638531	2188
	12-SIMP17-W	11	412325	5638542	2191
SKINNY	12-SKINNY-N	11	412317	5638618	2184
	12-SKINNY-S	11	412320	5638605	2184
	12-SKINNY-S01*	11	412319	5638609	2184
SMALL	12-SMALL-E	11	412654	5638717	2107
	12-SMALL-PEG	11	412640	5638730	2107
	12-SMALL-S01*	11	412639	5638728	2108
	12-SMALL-W	11	412629	5638729	2106
STUBBY	12-STUBBY-E	11	412509	5638844	2104
	12-STUBBY-W	11	412500	5638840	2106
THIN	12-THIN-M01	11	412061	5638934	2152
	12-THIN-M02	11	412068	5638935	2151

* Denotes sites where samples were taken

ALL PEGMATITE COORDINATES AND SAMPLE SITES (UTM, WGS 84) CONT'D

Pegmatite	Point Name	Zone	Easting	Northing	Elevation
THIN (cont'd)	12-THIN-M03	11	412074	5638930	2153
	12-THIN-M04	11	412079	5638928	2153
	12-THIN-M05	11	412086	5638924	2154
	12-THIN-M06	11	412093	5638915	2155
	12-THIN-M07	11	412095	5638917	2156
	12-THIN-M08	11	412102	5638914	2157
	12-THIN-M09	11	412103	5638912	2157
	12-THIN-S01*	11	412086	5638924	2154
	12-THIN-W	11	412049	5638939	2152
TINY	12-TINY-W	11	412558	5638744	2120
	12-GRANIT-SP03	11	412560	5638742	2121
TOUR	12-TOUR-M01	11	412492	5638482	2187
	12-TOUR-N	11	412485	5638491	2186
	12-TOUR-S	11	412496	5638477	2186
	12-TOUR-S01*	11	412491	5638486	2188
TOUR2	12-TOUR2-N	11	412438	5638535	2185
	12-TOUR2-S	11	412441	5638531	2186
TOURMUS	12-TOURMUS-M01	11	412546	5638751	2118
	12-TOURMUS-S01*	11	412546	5638751	2118
	12-TOURMUS-W	11	412524	5638769	2116
	12-GRANIT-SP01	11	412552	5638744	2121
WOBBLE	12-WOBBLE-M01	11	412367	5638545	2190
	12-WOBBLE-M02	11	412361	5638550	2190
	12-WOBBLE-N	11	412357	5638550	2190
	12-WOBBLE-S	11	412371	5638541	2191
	12-WOBBLE-S01*	11	412359	5638549	2190
	12-WOBBLE-S02*	11	412367	5638549	2191
XENO	12-XENO-PEG	11	412496	5638491	2181
ZONED	12-ZONED-E	11	412097	5638859	2177
	12-ZONED-M01	11	412055	5638888	2175
	12-ZONED-M02	11	412043	5638895	2175
	12-ZONED-PEG	11	412062	5638886	2180
	12-ZONED-S01*	11	412055	5638888	2175
	12-ZONED-S02*	11	412080	5638873	2177
	12-ZONED-W	11	412015	5638904	2174

* Denotes sites where samples were taken

Appendix B X-Ray Diffraction

B.1 Powder X-Ray Diffraction

Powder X-ray diffraction experiments were conducted to identify small and unusual crystalline masses using smear mounts. Samples were prepared by grinding in ethanol to a fine powder and smearing the resulting material onto an acrylic slide. Data was collected with a Bruker D8 Focus Bragg-Brentano diffractometer equipped with a Fe monochromator foil, 0.6 mm (0.3°) divergence slit, incident- and diffracted-beam Soller slits and a LynxEye detector. The long fine-focus Co X-ray tube was operated at 35 kV and 40 mA, using a take-off angle of 6° . Powder-diffraction data were collected over ranges of 3 to $80^\circ 2\theta$, with $\text{CoK}\alpha$ radiation. Scanning steps of $0.04^\circ 2\theta$ with a time per step of 0.5 s were used and the sample was spun at 50 rpm.

Phases were identified from the resulting powder X-ray diffraction patterns by peak matching using Search-Match software by Bruker (EVA 3.0) and the International Centre for Diffraction Database PDF-4. The results are shown below.

12-BERYL-S01

Note: Silicon carbide peaks are contamination from the tool used to remove specimens for powder XRD.

12-BERYL-S01

12-BERYL-S01

12-BERYL-S01

12-BERYL-S01

12-BERYL-S03 (core zone)

Appendix B.1

12-BERYL-S01

12-BERYL-S01

Appendix B.1

12-BERYL-S01

Note: Silicon carbide peaks are contamination from the tool used to remove specimens for powder XRD.

12-GAR-S01

Appendix B.1

12-GAR-S03

Appendix B.1

12-GAR-S03

Appendix B.1

12-GARPHOS-S04

12-GARPHOS-S04

Appendix B.1

12-GARPHOS-S04

Appendix B.1

12-GARPHOS-S04

Appendix B.1

250

12-GARPHOS-S04

Note: A positive identification of rutile may not be likely; the presence of a related oxide mineral is probable.

12-LI-S01

Note: A positive identification of columbite and ixiolite are unlikely; a related oxide might be responsible for the peaks beyond the upper angles for the petalite pattern.

12-LI-S01

Note: A positive identification of columbite is unlikely; a related oxide might be responsible for the peaks in the not matched by the petalite or muscovite patterns.

12-LI2-S03

Appendix B.1

12-LI2-S03

Appendix B.1

12-LI2-S01

Note: A positive identification for nontronite and illite are not probable with powder XRD smear mounts; the presence of an unidentified 15 Å clay is extremely likely. Future examination of the sample with powder XRD should ensure the sample is glycolated to get a better pattern.

12-LI2-S02 (intermediate zone)

12-SIMPLE16-S01

Note: A positive identification of rutile may not be likely; the presence of a related oxide mineral is probable.

12-TOURMUS-S01

B.2 Single-Crystal X-Ray Diffraction

The single-crystal X-ray diffraction experiment for the positive identification of secondary beryl was performed using a Bruker APEX-II CCD diffractometer at 296.15 K. The structure was solved using Olex2 with the solution program olex2.solve utilizing charge flipping; subsequent refinement was carried out with the olex2.refine refinement package using Gauss-Newton minimization (Dolomanov et al. 2009, Bourhis et al. 2011a, & Bourhis et al. 2011b). During the refinement process, O atoms were used to denote the possible locations of molecules and cations residing in the channel sites. Settings used in Olex2 prevented the use of cations from being used in the structure model. The experimental details and results can be seen below. The structural results correspond with EMP analyses 22be-1, 22be-2, and 22be-3.

EXPERIMENTAL DETAILS FOR THE SINGLE-CRYSTAL X-RAY DIFFRACTION STUDY OF SECONDARY BERYL

Color	translucent white
Dimensions of the crystal (mm)	ca. 0.10 × 0.10 × 0.10
<i>a</i> , <i>b</i> , <i>c</i> (Å)	9.2262(8), 9.2262(8), 9.2058(8)
α , β , γ (°)	90, 90, 120
<i>V</i> (Å ³)	678.64(10)
Space group	P6/mcc
<i>Z</i>	2
2 $\theta_{\min}$, 2 $\theta_{\max}$	5.1°, 72.98°
Range of indices	-14 ≤ <i>h</i> ≤ 15, -12 ≤ <i>k</i> ≤ 15, -14 ≤ <i>l</i> ≤ 15
Measured intensities	11433
Independent reflections [<i>R</i> (int) = 0.0211]	252
<i>m</i> /mm ⁻¹	0.911
Data/restraints/parameters	252/0/28
<i>R</i> ₁ [<i>I</i> > 2σ(<i>I</i>)]	0.0228
<i>R</i> ₁ (all)	0.0229
<i>wR</i> ₂ (all)	0.1083
Goodness-of-fit on <i>F</i> ²	1.093
Max peak and hole in the final ΔF map (e/Å ³)	+0.46 and -0.46

FINAL FRACTIONAL COORDINATES AND DISPLACEMENT PARAMETERS ($\text{\AA}^2$) OF ATOMS IN SECONDARY BERYL

Site	x	y	z	U_{11}	U_{22}	U_{33}	U_{12}	U_{13}	U_{23}	U_{eq}
Be	0	0.5	0.75	0.0015(16)	0.0016(12)	0.0078(16)	0.0008(8)	-0	0	0.0036(8)
Al	0.333333	0.666667	0.75	0.0079(5)	0.0079(5)	0.0079(8)	0.0039(3)	-0	0	0.0079(5)
Si	0.11598(6)	0.38791(6)	0.5	0.0035(6)	0.0037(5)	0.0037(6)	0.0018(3)	-0	0	0.0036(5)
O1	0.23657(16)	0.3099(2)	0.5	0.0068(9)	0.0069(8)	0.0078(9)	0.0044(6)	-0	0	0.0067(5)
O2	0.14596(15)	0.49910(14)	0.64521(12)	0.0053(5)	0.0060(7)	0.0055(7)	0.0028(4)	0.0013(4)	0.001(4)	0.0056(5)
O (H ₂ O)	0	0	0.75	—	—	—	—	—	—	0.0033(5)
O (Na)	0	0	0.5	—	—	—	—	—	—	0.0160(20)

TABLE 3. BOND DISTANCES (Å) AND ANGLES (°) IN SECONDARY BERYL

Al - O2 ³	1.9070(12)	O2 - Al - O2 ³	170.48(7)
Al - O2	1.9070(12)	O2 ⁴ - Al - O2 ³	90.81(7)
Al - O2 ⁴	1.9070(12)	O2 ⁴ - Al - O2	96.67(4)
Al - O2 ⁵	1.9070(12)	O2 ⁵ - Al - O2 ³	76.55(7)
Al - O2 ⁶	1.9070(12)	O2 ⁵ - Al - O2	96.67(4)
Al - O2 ⁷	1.9070(12)	O2 ⁵ - Al - O2 ⁴	96.67(4)
Si - O1	1.5989(14)	O2 ⁶ - Al - O2 ³	96.67(4)
Si - O1 ¹	1.6005(13)	O2 ⁶ - Al - O2	90.81(7)
Si - O2 ²	1.6223(12)	O2 ⁶ - Al - O2 ⁴	76.55(7)
Si - O2	1.6223(12)	O2 ⁶ - Al - O2 ⁵	170.48(7)
Be - O2 ⁸	1.6599(11)	O2 ⁷ - Al - O2 ³	96.67(4)
		O2 ⁷ - Al - O2	76.55(7)
		O2 ⁷ - Al - O2 ⁴	170.48(7)
		O2 ⁷ - Al - O2 ⁵	90.81(7)
		O2 ⁷ - Al - O2 ⁶	96.67(4)
		O2 ² - Si - O1	110.34(6)
		O2 ² - Si - O1 ¹	108.56(6)
		O2 - Si - O1	110.34(6)
		O2 - Si - O1 ¹	108.56(6)
		O2 - Si - O2 ²	110.97(8)
		Al ³ - O2 - Si ²	136.74(7)
		Be ⁸ - O2 - Si ²	126.85(8)
		Be ⁸ - O2 - Al ³	96.36(5)
		O2 - Be - O2 ⁸	131.51(8)
		O2 ⁹ - Be - O2 ⁸	90.73(8)
		O2 ⁹ - Be - O2	108.93(9)
		O2 ⁷ - Be - O2 ⁸	108.93(9)
		O2 ⁷ - Be - O2	90.73(8)
		O2 ⁷ - Be - O2 ⁹	131.51(8)

Note: Symmetry transformations are used to generate equivalent atoms ¹-y+x, +x, +z; ²+x, +y, 1-z; ³1-y, 1-x, 3/2-z; ⁴1-y, 1+x-y, +z; ⁵+y-x, 1-x, +z; ⁶+y-x, +y, 3/2-z; ⁷+x, 1+x-y, 3/2-z; ⁸-x, -x+y, 3/2-z; ⁹-x, 1-y, +z.

Appendix C EMPA Methods

C.1 Tourmaline and Topaz

Electron microprobe analyses of tourmaline (except for those containing Bi) and for topaz were done on a fully automated CAMECA SX-50 instrument operating in the wavelength-dispersion mode with the following operating conditions: excitation voltage, 15 kV; beam current, 20 nA; peak count time, 20 s (40 s for F and Cl); background count-time, 10 s (20 s for F and Cl); spot diameter, 5 μm . Data reduction was done using the 'PAP' $\phi(\rho Z)$ method (Pouchou & Pichoir 1985). B was fixed at the nominal value (3.25 wt. %). For the elements considered, the following standards, X-ray lines, and crystals were used: synthetic fluorophlogopite, FK_{α} , TAP; albite, NaK_{α} , TAP; kyanite, AlK_{α} , TAP; diopside, MgK_{α} , TAP; diopside, SiK_{α} , TAP; scapolite, ClK_{α} , PET; orthoclase, KK_{α} , PET; diopside, CaK_{α} , PET; rutile, TiK_{α} , PET; synthetic magnesiochromite, CrK_{α} , LIF; synthetic rhodonite, MnK_{α} , LIF; synthetic fayalite, FeK_{α} , LIF; gahnite, ZnK_{α} , LIF.

EMP analyses of tourmaline containing Bi were done on a CAMECA SX-100 instrument operating the wavelength dispersion mode with the following operating conditions: excitation voltage, 15 kV; beam current, 20 nA; peak count time, 20 s (30 s for F); background count-time, 10 s (15 s for F); spot diameter, 5 μm . B was fixed at a value of 3.11 wt. %. For the elements considered, the following standards, X-ray lines, and crystals were used: F-riebeckite, FK_{α} , LTAP; albite, NaK_{α} , TAP; andalusite, AlK_{α} , TAP; olivine, MgK_{α} , LTAP; diopside, SiK_{α} , TAP; tugtuphite, ClK_{α} , LPET; orthoclase, KK_{α} , LPET; diopside, CaK_{α} , LPET; sphene, TiK_{α} , LPET; chromite, CrK_{α} , LLIF; spessartine, MnK_{α} , LLIF; fayalite, FeK_{α} , LLIF; gahnite, ZnK_{α} , LLIF; Bi_2O_3 , BiM_{α} , LPET.

C.2 K-Feldspar, Muscovite, Lepidolite, and Biotite

EMP analyses K-feldspar, muscovite, lepidolite, and biotite were done on a CAMECA SX-100 instrument, operating the wavelength dispersion mode with the following operating conditions: excitation voltage, 15 kV; beam current, 20 nA; peak count time, 20 s (30 s for F); background count-time, 10 s (15 s for F); spot diameter, 10 μm . For the elements considered, the following standards, X-ray lines, and crystals were used: F-riebeckite, FK_{α} , LTAP; albite, NaK_{α} , TAP; olivine, MgK_{α} , LTAP; diopside, SiK_{α} , TAP; andalusite, AlK_{α} , TAP; orthoclase, KK_{α} , LPET; diopside, CaK_{α} , LPET; SrTiO_3 , SrL_{α} , LPET; apatite, PK_{α} , LPET; pollucite, CsL_{α} , LPET; fayalite, FeK_{α} , LLIF; spessartine, MnK_{α} , LLIF; sphene, TiK_{α} , LLIF; $\text{Ba}_2\text{NaNb}_5\text{O}_{15}$, BaL_{β} , LLIF; gahnite, ZnK_{α} , LLIF; PbTe, PbM_{β} , LPET; Rb-leucite, RbL_{α} , LTAP.

C.3 Garnet and Sektinaite

EMP analyses of garnet and cordierite were done on a fully automated CAMECA SX-50 instrument, operating in the wavelength-dispersion mode with the following operating conditions: excitation voltage, 15 kV; beam current, 20 nA; peak count time, 20 s; background count-time, 10 s; spot diameter, 5 μm . Data reduction was done using the 'PAP' $\phi(\rho Z)$ method (Pouchou & Pichoir 1985). For the elements considered, the following standards, X-ray lines and crystals were used: albite, NaK_{α} , TAP; almandine, MgK_{α} , TAP; almandine, AlK_{α} , TAP; almandine, SiK_{α} , TAP; orthoclase, KK_{α} , PET; apatite, PK_{α} , PET; rutile, TiK_{α} , PET; grossular, CaK_{α} , PET; magnesiochromite, CrK_{α} , LIF; synthetic rhodonite, MnK_{α} , LIF; almandine, FeK_{α} , LIF.

C.4 Beryl, Bertrandite, and Chrysoberyl

EMP analyses of beryl, bertrandite, and chrysoberyl were done on a fully automated CAMECA SX-50 instrument operating in the wavelength-dispersion mode with the following operating conditions: excitation voltage, 15 kV; beam current, 20 nA, peak count time, 50s, background count-time, 25s (Na, Al, Si peak count time, 20s, background count-time, 10s); spot diameter (standards and specimen), 10 μm . Data reduction was done using the 'PAP' $\phi(\rho Z)$ method (Pouchou & Pichoir 1985). For the elements considered, the following standards, X-ray lines, and crystals were used: albite, NaK_{α} , AlK_{α} , SiK_{α} , TAP; diopside, MgK_{α} , TAP; diopside, CaK_{α} , PET; orthoclase, KK_{α} , PET; elemental Sc, ScK_{α} , PET; rutile, TiK_{α} , PET; elemental V, VK_{α} , PET; synthetic magnesiochromite, CrK_{α} , LIF; synthetic rhodonite, MnK_{α} , LIF; synthetic fayalite, FeK_{α} , LIF; pollucite, CsL_{α} , PET.

C.5 Columbite-Tantalite, Rutile, Cassiterite, Wolframite, and Qitianlingite

EMP analyses of columbite-tantalite, rutile, cassiterite, wolframite, and qitianlingite were done on a CAMECA SX-100 instrument, operating the wavelength dispersion mode with the following operating conditions: excitation voltage, 15 kV; beam current, 20 nA; peak count time, 20 s (10 s for Th, 30 s for F); background count-time, 10 s (15 s for F); spot diameter, 10 μm . For the elements considered, the following standards, X-ray lines, and crystals were used: apatite, FK_{α} , LTAP, LPC0; albite, NaK_{α} , TAP; olivine, MgK_{α} , LTAP; diopside, SiK_{α} , TAP; andalusite, AlK_{α} , TAP; diopside, CaK_{α} , LPET; fayalite, FeK_{α} , LLIF; spessartine, MnK_{α} , LLIF; sphene, TiK_{α} , LPET; ScPO_4 , ScK_{α} , LPET; cobalt, AsL_{α} , TAP; YPO_4 , YL_{α} , LPET; $\text{Ba}_2\text{NaNb}_5\text{O}_{15}$, NbL_{α} , LPET; SnO_2 , SnL_{α} , LPET; stibiotantalite, SbL_{α} , LPET; LaPO_4 , LaL_{α} , LLIF; CePO_4 , CeL_{α} , LLIF; PrPO_4 , PrL_{β} , LLIF; NdPO_4 , NdL_{β} , LLIF; SmPO_4 , SmL_{β} , LLIF; EuPO_4 , EuL_{β} , LLIF; GdPO_4 , GdL_{β} , LLIF; TbPO_4 , TbL_{α} , LLIF; DyPO_4 , DyL_{β} , LLIF; HoPO_4 , HoL_{β} , LLIF; ErPO_4 , ErL_{α} , LLIF; TmPO_4 , TmL_{α} , LLIF; YbPO_4 , YbM_{α} , TAP; $\text{MnNb}_2\text{Ta}_2\text{O}_9$, TaM_{α} , TAP; CaWO_4 , WM_{α} , LPET; Bi_2O_3 , BiM_{α} , LPET; ThO_2 , ThM_{α} , LPET; UO_2 , UM_{α} , LPET; ZrO_2 , ZrL_{α} , LPET.

C.6 Monazite and Xenotime

EMP analyses of monazite and xenotime were done on a CAMECA SX-100 instrument, operating the wavelength dispersion mode with the following operating conditions: excitation voltage, 15 kV; beam current, 20 nA; peak count time, 20 s (10 s for Th, 30 s for F); background count-time, 10 s (15 s for F); spot diameter, 1 μm . For the elements considered, the following standards, X-ray lines, and crystals were used: apatite, FK_{α} , LTAP, LPC0; albite, NaK_{α} , TAP; olivine, MgK_{α} , LTAP; diopside, SiK_{α} , TAP; andalusite, AlK_{α} , TAP; orthoclase, KK_{α} , LPET; diopside, CaK_{α} , LPET; apatite, PK_{α} , LPET; fayalite, FeK_{α} , LLIF; spessartine, MnK_{α} , LLIF; sphene, TiK_{α} , LPET; ScPO_4 , ScK_{α} , LPET; cobalt, AsL_{α} , TAP; YPO_4 , YL_{α} , LPET; $\text{Ba}_2\text{NaNb}_5\text{O}_{15}$, NbL_{α} , LPET; SnO_2 , SnL_{α} , LPET; stibiotantalite, SbL_{α} , LPET; LaPO_4 , LaL_{α} , LLIF; CePO_4 , CeL_{α} , LLIF; PrPO_4 , PrL_{β} , LLIF; NdPO_4 , NdL_{β} , LLIF; SmPO_4 , SmL_{β} , LLIF; EuPO_4 , EuL_{β} , LLIF; GdPO_4 , GdL_{β} , LLIF; TbPO_4 , TbL_{α} , LLIF; DyPO_4 , DyL_{β} , LLIF; HoPO_4 , HoL_{β} , LLIF; ErPO_4 , ErL_{α} , LLIF; TmPO_4 , TmL_{α} , LLIF; YbPO_4 , YbM_{α} , TAP; $\text{MnNb}_2\text{Ta}_2\text{O}_9$, TaM_{α} , TAP; CaWO_4 , WM_{α} , LPET; Bi_2O_3 , BiM_{α} , LPET; ThO_2 , ThM_{α} , LPET; UO_2 , UM_{α} , LPET; ZrO_2 , ZrL_{α} , LPET.

C.7 Zircon

EMP analyses of monazite and xenotime were done on a CAMECA SX-100 instrument, operating the wavelength dispersion mode with the following operating conditions: excitation voltage, 15 kV; beam current, 20 nA; peak count time, 20 s (10 s for Th); background count-time, 10 s; spot diameter, 1 μm . For the elements considered, the following standards, X-ray lines, and crystals were used: diopside, SiK_{α} , TAP; andalusite, AlK_{α} , TAP; olivine, MgK_{α} , LTAP; fayalite, FeK_{α} , LLIF; spessartine, MnK_{α} , LLIF; ZrO_2 , ZrL_{α} , LPET; YPO_4 , YL_{α} , LPET; sphene, TiK_{α} , LPET; ScPO_4 , ScK_{α} , LPET; LaPO_4 , LaL_{α} , LLIF; CePO_4 , CeL_{α} , LLIF; PrPO_4 , PrL_{β} , LLIF; NdPO_4 , NdL_{β} , LLIF; SmPO_4 , SmL_{β} , LLIF; EuPO_4 , EuL_{β} , LLIF; GdPO_4 , GdL_{β} , LLIF; TbPO_4 , TbL_{α} , LLIF; DyPO_4 , DyL_{β} , LLIF; HoPO_4 , HoL_{β} , LLIF; ErPO_4 , ErL_{α} , LLIF; TmPO_4 , TmL_{α} , LLIF; YbPO_4 , YbM_{α} , TAP; Bi_2O_3 , BiM_{α} , LPET; ThO_2 , ThM_{α} , LPET; UO_2 , UM_{α} , LPET; HfSiO_4 , HfL_{α} , LLIF; PbTe , PbM_{β} , LPET.

Appendix D EMPA Results

Appendix D.1: Electron-microprobe analyses of tourmaline.

Site	BERYL-S02				BERYL-S03A		BERYL-S03B				BERYL-S03B	
Comments	bigger blk tur: core	bigger blk tur: core	bigger blk tur: rim	bigger blk tur: rim	homogeneous medium-sized blk tur; partial replacement by mica	homogeneous medium-sized blk tur; partial replacement by mica	lightly zoned bland tur: core	lightly zoned bland tur: core	lightly zoned bland tur: rim	lightly zoned bland tur: rim	bt + tur contact; homogeneous tur	bt + tur contact; homogeneous tur
Point	27t-1	27t-2	27t-3	27t-4	28t-1	28t-2	29t-1	29t-2	29t-3	29t-4	30t-1	30t-2
SiO ₂ (wt.%)	34.31	34.50	34.59	34.91	33.38	33.54	35.11	34.35	34.12	33.90	35.10	34.55
TiO ₂	0.19	0.17	0.41	0.35	0.67	0.57	0.80	0.84	0.30	0.56	0.98	1.34
B ₂ O ₃ *	10.39	10.39	10.41	10.44	10.32	10.32	10.40	10.30	10.16	10.15	10.38	10.26
Al ₂ O ₃	35.68	35.80	35.01	34.92	34.25	34.53	32.44	32.52	31.78	31.64	31.69	30.87
Cr ₂ O ₃	0.00	0.00	0.02	0.00	0.02	0.00	0.00	0.00	0.01	0.00	0.02	0.00
Bi ₂ O ₃												
Fe ₂ O ₃ *	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO*	13.10	12.93	13.37	13.51	8.62	8.68	11.55	11.55	13.60	13.43	11.85	12.07
FeO (tot)	13.10	12.93	13.37	13.51	8.62	8.68	11.55	11.55	13.60	13.43	11.85	12.07
MnO	0.41	0.31	0.43	0.39	0.09	0.03	0.20	0.22	0.17	0.14	0.16	0.14
ZnO	0.13	0.02	0.00	0.10	0.03	0.00	0.13	0.00	0.10	0.13	0.07	0.03
MgO	0.75	0.75	0.88	0.89	4.88	4.59	3.55	3.55	2.83	2.90	3.87	3.84
Li ₂ O*	0.16	0.15	0.20	0.18	0.06	0.07	0.14	0.11	0.02	0.05	0.13	0.16
CaO	0.06	0.06	0.13	0.10	0.54	0.44	0.28	0.31	0.58	0.65	0.38	0.54
Na ₂ O	1.59	1.31	1.67	1.55	1.93	1.78	2.02	2.09	1.92	1.97	2.09	2.10
K ₂ O	0.02	0.03	0.04	0.06	0.05	0.03	0.04	0.05	0.01	0.04	0.05	0.04
F	0.13	0.19	0.49	0.17	0.25	0.13	0.73	0.61	0.74	0.95	0.79	1.09
Cl	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00
H ₂ O*	3.52	3.49	3.36	3.52	3.44	3.50	3.24	3.27	3.15	3.05	3.20	3.02
-(O=F,Cl)	-0.06	-0.08	-0.21	-0.07	-0.10	-0.05	-0.31	-0.26	-0.31	-0.40	-0.34	-0.46
Total	100.39	100.02	100.81	101.02	98.43	98.15	100.33	99.52	99.19	99.17	100.45	99.59
T Si (apfu)	5.741	5.773	5.774	5.814	5.620	5.649	5.869	5.795	5.837	5.805	5.877	5.854
T Al	0.259	0.227	0.226	0.186	0.380	0.351	0.131	0.205	0.163	0.195	0.123	0.146
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.024	0.021	0.051	0.044	0.085	0.072	0.101	0.107	0.038	0.072	0.124	0.171
Y Al	0.776	0.834	0.662	0.668	0.416	0.503	0.260	0.261	0.244	0.190	0.131	0.018
Y Cr	0.000	0.000	0.003	0.001	0.003	0.000	0.000	0.001	0.001	0.000	0.003	0.000
Y Fe ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y Fe ²⁺	1.834	1.809	1.866	1.881	1.214	1.222	1.615	1.629	1.945	1.923	1.659	1.710
Y Mn	0.059	0.044	0.061	0.056	0.013	0.004	0.028	0.032	0.025	0.020	0.023	0.020
Y Zn	0.017	0.003	0.000	0.012	0.003	0.000	0.016	0.000	0.012	0.017	0.009	0.004
Y Mg	0.186	0.186	0.220	0.220	1.225	1.152	0.884	0.894	0.723	0.740	0.966	0.971
Y Li	0.105	0.102	0.136	0.118	0.041	0.046	0.096	0.077	0.012	0.038	0.084	0.107
X Ca	0.010	0.010	0.022	0.018	0.097	0.080	0.051	0.056	0.106	0.118	0.068	0.098
X Na	0.516	0.426	0.542	0.501	0.630	0.582	0.655	0.682	0.638	0.654	0.678	0.690
x K	0.005	0.006	0.009	0.012	0.010	0.007	0.009	0.011	0.003	0.008	0.011	0.008
X vac	0.469	0.558	0.427	0.469	0.264	0.331	0.286	0.250	0.252	0.220	0.243	0.204
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.067	0.100	0.257	0.087	0.131	0.067	0.385	0.325	0.399	0.514	0.421	0.586
W Cl	0.003	0.000	0.001	0.000	0.000	0.000	0.001	0.000	0.002	0.000	0.002	0.001
W OH	0.930	0.899	0.742	0.913	0.869	0.933	0.614	0.675	0.599	0.486	0.577	0.413
W O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Classif.	schorl	foitite	schorl	schorl	dravite	schorl	schorl	schorl	schorl	fluor-schorl	schorl	fluor-schorl

*Note: tourmaline formula was calculated on the basis of 31 anions (O, OH, F, Cl), B=3 apfu, and Li=15-(T+Z+Y) or T+Z+Y=15 for Li-bearing samples and Li-free samples, respectively; ratio of Fe₂O₃ and FeO calculated to fit electroneutral formula.

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site	BERYL-S03C	BERYL-S03E		BERYL-S04		BERYL-S04		BERYL-S04				
Comments	delightfully homogeneous biggish tur	delightfully homogeneous biggish tur	inner intermediate zone; homogeneous tiny tur xtl partially replaced by micas and fe-oxides	inner intermediate zone; homogeneous tiny tur xtl partially replaced by micas and fe-oxides	border/intermediate zone?; homogeneous and partially replaced by micas	border/intermediate zone?; homogeneous and partially replaced by micas	wall zone; homogeneous and appears zoned due to replacement by micas and increased porosity	wall zone; homogeneous and appears zoned due to replacement by micas and increased porosity	intermediate two-toned tur: core	intermediate two-toned tur: core	intermediate two-toned tur: rim	intermediate two-toned tur: rim
Point	31t-1	31t-2	32t-1	32t-2	33t-1	33t-2	34t-1	34t-2	35t-1	35t-2	35t-3	35t-4
SiO ₂ (wt.%)	33.86	34.38	34.89	34.20	34.87	34.54	34.71	35.16	35.00	34.61	34.01	33.99
TiO ₂	0.49	0.88	0.23	0.15	0.43	0.45	0.89	0.86	0.59	0.51	0.47	0.44
B ₂ O ₃ *	10.28	10.33	10.42	10.32	10.41	10.34	10.40	10.46	10.50	10.40	10.32	10.30
Al ₂ O ₃	34.13	33.57	35.00	34.87	35.05	34.79	33.78	33.78	34.49	34.39	34.66	34.61
Cr ₂ O ₃	0.03	0.00	0.01	0.00	0.00	0.00	0.00	0.05	0.01	0.00	0.02	0.01
Bi ₂ O ₃												
Fe ₂ O ₃ *	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO*	13.34	12.88	13.43	13.73	13.46	13.70	12.86	12.39	10.91	10.67	12.90	13.32
FeO (tot)	13.34	12.88	13.43	13.73	13.46	13.70	12.86	12.39	10.91	10.67	12.90	13.32
MnO	0.37	0.22	0.62	0.63	0.57	0.46	0.16	0.16	0.13	0.13	0.46	0.38
ZnO	0.09	0.03	0.14	0.22	0.11	0.05	0.08	0.03	0.04	0.06	0.10	0.14
MgO	1.25	1.96	0.31	0.30	0.40	0.42	1.95	1.94	2.96	2.91	1.23	1.13
Li ₂ O*	0.22	0.15	0.33	0.26	0.22	0.21	0.18	0.31	0.20	0.21	0.19	0.13
CaO	0.29	0.24	0.09	0.06	0.07	0.08	0.19	0.22	0.28	0.31	0.18	0.15
Na ₂ O	2.02	1.68	1.88	2.04	1.43	1.53	1.76	1.88	1.74	1.74	1.82	1.73
K ₂ O	0.03	0.04	0.03	0.05	0.03	0.02	0.03	0.04	0.04	0.04	0.03	0.05
F	1.16	0.43	1.05	1.00	0.64	0.45	0.30	0.27	0.22	0.19	0.40	0.59
Cl	0.00	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
H ₂ O*	3.00	3.35	3.09	3.09	3.29	3.35	3.45	3.48	3.52	3.50	3.37	3.27
-(O=F,Cl)	-0.49	-0.19	-0.45	-0.42	-0.27	-0.19	-0.13	-0.11	-0.09	-0.08	-0.17	-0.25
Total	100.07	99.98	101.10	100.50	100.70	100.21	100.60	100.91	100.53	99.59	100.01	100.00
T Si (apfu)	5.723	5.786	5.817	5.759	5.824	5.805	5.800	5.840	5.795	5.781	5.728	5.735
T Al	0.277	0.214	0.183	0.241	0.176	0.195	0.200	0.160	0.205	0.219	0.272	0.265
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.063	0.112	0.028	0.019	0.054	0.057	0.112	0.107	0.073	0.064	0.060	0.055
Y Al	0.521	0.446	0.696	0.680	0.724	0.695	0.452	0.454	0.526	0.552	0.608	0.617
Y Cr	0.004	0.000	0.001	0.000	0.000	0.000	0.001	0.006	0.001	0.000	0.003	0.001
Y Fe ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y Fe ²⁺	1.886	1.814	1.872	1.933	1.880	1.926	1.797	1.721	1.511	1.491	1.817	1.880
Y Mn	0.054	0.031	0.088	0.090	0.080	0.065	0.022	0.023	0.019	0.018	0.066	0.054
Y Zn	0.011	0.004	0.018	0.027	0.013	0.006	0.010	0.004	0.004	0.007	0.013	0.018
Y Mg	0.315	0.492	0.078	0.076	0.098	0.106	0.485	0.481	0.730	0.724	0.308	0.283
Y Li	0.147	0.101	0.218	0.176	0.150	0.145	0.121	0.204	0.135	0.143	0.127	0.091
X Ca	0.052	0.044	0.016	0.012	0.012	0.014	0.035	0.038	0.050	0.056	0.033	0.027
X Na	0.663	0.549	0.609	0.666	0.463	0.498	0.569	0.604	0.559	0.563	0.596	0.564
x K	0.007	0.009	0.007	0.011	0.007	0.005	0.007	0.009	0.008	0.008	0.007	0.010
X vac	0.278	0.399	0.369	0.312	0.518	0.483	0.390	0.348	0.383	0.373	0.364	0.399
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.619	0.230	0.556	0.534	0.337	0.239	0.158	0.140	0.113	0.101	0.214	0.317
W Cl	0.000	0.004	0.004	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004
W OH	0.380	0.766	0.439	0.466	0.663	0.761	0.842	0.860	0.887	0.899	0.786	0.679
W O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Classif.	fluor-schorl	schorl	fluor-schorl	fluor-schorl	foitite	schorl	schorl	schorl	schorl	schorl	schorl	schorl

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site	CORD-S01		CORD-S01		CORD-S03		GAR-S01		GAR-S01			
Comments	homogeneous blue tur partially replaced by mica and Fe-oxide	homogeneous blue tur partially replaced by mica and Fe-oxide	black tur: core	black tur: core	black tur: rim	black tur: rim	black homogeneous tur laced with Fe-oxide	black homogeneous tur laced with Fe-oxide	center tur (homogeneous)	center tur (homogeneous)	wall tur core	wall tur core
Point	36t-1	36t-2	38t-1	38t-2	38t-3	38t-4	37t-1	37t-2	39t-1	39t-2	41t-1	41t-2
SiO ₂ (wt.%)	37.09	36.41	36.02	36.59	35.96	36.39	35.71	35.86	35.94	35.81	35.17	35.39
TiO ₂	0.01	0.00	0.22	0.20	0.20	0.33	0.32	0.61	0.42	0.43	0.21	0.14
B ₂ O ₃ *	10.89	10.82	10.78	10.90	10.65	10.72	10.64	10.72	10.56	10.56	10.54	10.51
Al ₂ O ₃	35.40	35.71	35.37	35.59	34.73	34.91	36.32	35.56	32.73	33.10	34.40	34.34
Cr ₂ O ₃	0.00	0.02	0.00	0.00	0.00	0.00	0.05	0.05	0.00	0.03	0.06	0.03
Bi ₂ O ₃												
Fe ₂ O ₃ *	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO*	5.68	5.70	6.35	6.41	9.15	8.83	9.31	9.93	10.43	10.41	8.39	8.22
FeO (tot)	5.68	5.70	6.35	6.41	9.15	8.83	9.31	9.93	10.43	10.41	8.39	8.22
MnO	0.14	0.06	0.13	0.11	0.16	0.12	0.13	0.14	0.12	0.12	0.05	0.08
ZnO	0.00	0.00	0.00	0.03	0.00	0.04	0.00	0.01	0.04	0.09	0.00	0.06
MgO	6.07	6.11	5.83	5.92	4.19	4.06	2.56	2.93	4.48	4.42	5.36	5.21
Li ₂ O*	0.31	0.23	0.27	0.27	0.21	0.30	0.33	0.37	0.19	0.12	0.00	0.00
CaO	0.39	0.36	0.55	0.56	0.32	0.36	0.15	0.29	0.33	0.33	0.36	0.36
Na ₂ O	1.82	1.78	1.91	1.84	1.78	1.63	1.29	1.77	2.22	2.00	1.66	1.74
K ₂ O	0.04	0.02	0.02	0.03	0.02	0.03	0.03	0.03	0.04	0.04	0.03	0.04
F	0.16	0.12	0.22	0.31	0.17	0.09	0.12	0.05	0.11	0.17	0.17	0.20
Cl	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00
H ₂ O*	3.68	3.67	3.61	3.61	3.59	3.66	3.61	3.67	3.59	3.56	3.55	3.42
-(O=F,Cl)	-0.07	-0.05	-0.10	-0.13	-0.07	-0.04	-0.05	-0.02	-0.05	-0.08	-0.07	-0.09
Total	101.63	100.97	101.19	102.25	101.08	101.44	100.51	101.97	101.14	101.14	99.88	99.65
T Si (apfu)	5.918	5.849	5.806	5.834	5.867	5.899	5.835	5.813	5.918	5.894	5.799	5.851
T Al	0.082	0.151	0.194	0.166	0.133	0.101	0.165	0.187	0.082	0.106	0.201	0.149
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.001	0.000	0.026	0.024	0.025	0.040	0.040	0.074	0.052	0.054	0.026	0.017
Y Al	0.576	0.612	0.525	0.522	0.544	0.567	0.828	0.607	0.269	0.314	0.485	0.540
Y Cr	0.000	0.003	0.000	0.000	0.000	0.000	0.006	0.007	0.000	0.004	0.008	0.003
Y Fe ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y Fe ²⁺	0.758	0.766	0.856	0.855	1.249	1.197	1.272	1.346	1.436	1.433	1.157	1.137
Y Mn	0.019	0.008	0.018	0.014	0.023	0.017	0.018	0.019	0.016	0.017	0.007	0.011
Y Zn	0.000	0.000	0.000	0.003	0.000	0.004	0.000	0.001	0.005	0.011	0.000	0.008
Y Mg	1.444	1.463	1.400	1.408	1.019	0.982	0.623	0.707	1.099	1.084	1.317	1.283
Y Li	0.201	0.148	0.174	0.173	0.140	0.192	0.214	0.240	0.123	0.082	0.000	0.000
X Ca	0.066	0.063	0.095	0.096	0.055	0.062	0.025	0.051	0.058	0.059	0.064	0.064
X Na	0.564	0.554	0.597	0.568	0.563	0.513	0.409	0.558	0.707	0.638	0.530	0.557
x K	0.008	0.005	0.004	0.007	0.005	0.007	0.006	0.007	0.009	0.008	0.007	0.008
X vac	0.361	0.379	0.305	0.328	0.376	0.417	0.559	0.385	0.226	0.295	0.399	0.372
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.082	0.060	0.114	0.158	0.089	0.044	0.061	0.027	0.059	0.091	0.088	0.106
W Cl	0.001	0.001	0.003	0.000	0.000	0.000	0.000	0.000	0.002	0.003	0.001	0.001
W OH	0.917	0.939	0.884	0.842	0.910	0.956	0.939	0.973	0.939	0.907	0.901	0.771
W O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.009	0.121
Classif.	dravite	dravite	dravite	dravite	schorl	schorl	foitite	schorl	schorl	schorl	dravite	dravite

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site	GAR-S01				GAR-S01-2				GAR-S01-5			
Comments	wall tur rim	wall tur rim	contact tur	contact tur	tiny tur in cordierite xtl: core	tiny tur in cordierite xtl: core	tiny tur in cordierite xtl: rim	tiny tur in cordierite xtl: rim	long tur at cordierite xtl contact: core	long tur at cordierite xtl contact: core	long tur at cordierite xtl contact: rim	long tur at cordierite xtl contact: rim
Point	41t-3	41t-4	42t-1	42t-2	GRT-1	GRT-2	GRT-3	GRT-4	GR5t1	GR5t2	GR5t3	GR5t4
SiO ₂ (wt.%)	35.07	34.53	35.60	35.64	35.34	34.71	35.76	35.47	35.47	34.85	34.83	35.01
TiO ₂	0.35	0.42	0.43	0.42	0.08	0.07	0.02	0.00	0.00	0.00	0.00	0.02
B ₂ O ₃ *	10.37	10.36	10.54	10.60	10.39	10.37	10.46	10.48	10.40	10.34	10.36	10.37
Al ₂ O ₃	32.82	32.86	33.75	34.10	32.66	32.91	31.92	32.38	31.82	33.66	31.82	31.99
Cr ₂ O ₃	0.00	0.00	0.00	0.02	0.00	0.04	0.03	0.00	0.00	0.03	0.01	0.02
Bi ₂ O ₃												
Fe ₂ O ₃ *	0.00	0.43	0.00	0.00	0.00	0.53	0.58	0.54	1.11	0.00	1.41	0.88
FeO*	10.82	11.14	7.76	7.87	12.00	11.74	9.16	8.99	10.41	11.11	9.46	10.02
FeO (tot)	10.82	11.52	7.76	7.87	12.00	12.21	9.68	9.47	11.41	11.11	10.73	10.81
MnO	0.22	0.19	0.09	0.08	0.25	0.16	0.20	0.22	0.25	0.23	0.25	0.19
ZnO	0.00	0.09	0.03	0.01	0.06	0.06	0.00	0.05	0.07	0.00	0.00	0.05
MgO	4.19	4.03	5.81	5.81	3.69	3.70	5.78	5.80	4.68	3.52	5.30	5.03
Li 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
CaO	0.40	0.40	0.67	0.75	0.19	0.18	0.20	0.22	0.26	0.12	0.22	0.27
Na ₂ O	2.10	1.90	1.93	1.75	2.17	2.17	2.20	2.33	1.96	1.88	2.34	2.21
K ₂ O	0.05	0.01	0.06	0.05	0.04	0.03	0.03	0.03	0.03	0.05	0.02	0.04
F	0.29	0.22	0.19	0.17	0.25	0.19	0.43	0.70	0.51	0.39	0.57	0.64
Cl	0.00	0.00	0.01	0.00	0.01	0.01	0.00	0.01	0.00	0.01	0.00	0.01
H ₂ O*	3.29	3.47	3.29	3.38	3.41	3.49	3.41	3.28	3.35	3.34	3.31	3.27
-(O=F,Cl)	-0.12	-0.09	-0.08	-0.07	-0.10	-0.08	-0.18	-0.30	-0.22	-0.17	-0.24	-0.27
Total	99.85	99.96	100.08	100.58	100.43	100.27	100.00	100.21	100.12	99.37	99.65	99.76
T Si (apfu)	5.878	5.790	5.872	5.844	5.911	5.817	5.940	5.883	5.928	5.855	5.843	5.869
T Al	0.122	0.210	0.128	0.156	0.089	0.183	0.060	0.117	0.072	0.145	0.157	0.131
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.044	0.053	0.053	0.052	0.009	0.008	0.003	0.000	0.001	0.000	0.000	0.003
Y Al	0.361	0.285	0.432	0.433	0.350	0.318	0.190	0.213	0.195	0.521	0.133	0.189
Y Cr	0.001	0.000	0.001	0.002	0.000	0.005	0.004	0.000	0.000	0.004	0.001	0.002
Y Fe ³⁺	0.000	0.054	0.000	0.000	0.000	0.067	0.073	0.067	0.139	0.000	0.178	0.111
Y Fe ²⁺	1.517	1.562	1.071	1.080	1.679	1.645	1.272	1.246	1.455	1.561	1.327	1.405
Y Mn	0.032	0.027	0.012	0.010	0.035	0.023	0.028	0.032	0.036	0.033	0.036	0.027
Y Zn	0.000	0.012	0.004	0.002	0.007	0.008	0.000	0.006	0.008	0.000	0.000	0.006
Y Mg	1.046	1.007	1.427	1.421	0.920	0.925	1.430	1.435	1.166	0.882	1.325	1.257
Y Li	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
X Ca	0.073	0.072	0.119	0.132	0.033	0.031	0.036	0.040	0.047	0.022	0.040	0.048
X Na	0.682	0.618	0.617	0.558	0.705	0.706	0.708	0.750	0.636	0.611	0.761	0.719
x K	0.010	0.003	0.013	0.011	0.009	0.006	0.007	0.007	0.007	0.010	0.004	0.010
X vac	0.236	0.307	0.252	0.300	0.253	0.256	0.249	0.203	0.310	0.357	0.195	0.223
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.154	0.114	0.097	0.090	0.130	0.101	0.226	0.366	0.270	0.208	0.300	0.338
W Cl	0.000	0.000	0.002	0.000	0.002	0.002	0.000	0.003	0.000	0.002	0.001	0.002
W OH	0.681	0.886	0.622	0.693	0.808	0.897	0.774	0.631	0.730	0.745	0.699	0.660
W O	0.165	0.000	0.279	0.216	0.060	0.000	0.000	0.000	0.000	0.045	0.000	0.000
Classif.	schorl	schorl	dravite	dravite	schorl	schorl	dravite	dravite	schorl	schorl	schorl	schorl

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site	GAR-S03			GARMUS-S01				GARMUS-S01			GARMUS-S	
Comments	fat and intergrowth tur (homogeneous)	center tur (homogeneous minus mica and qtz)	center tur (homogeneous minus mica and qtz)	wall zone tur: core	wall zone tur: core	wall zone tur: intermediate	wall zone tur: intermediate	wall zone tur: rim	wall zone tur: rim	border zone tur	border zone tur	border zone tur
Point	43t-2	44t-1	44t-2	45t-1	45t-2	45t-3	45t-4	45t-5	45t-6	46t-1	46t-2	47t-1
SiO ₂ (wt.%)	35.37	35.54	35.25	34.96	34.93	34.85	34.67	33.75	33.65	35.03	34.92	35.16
TiO ₂	0.42	0.43	0.51	0.33	0.13	0.46	0.62	0.76	0.75	0.57	0.77	0.42
B ₂ O ₃ *	10.42	10.53	10.50	10.45	10.33	10.36	10.32	10.30	10.26	10.42	10.35	10.49
Al ₂ O ₃	32.29	33.52	33.60	33.43	33.34	32.85	33.02	33.79	34.16	32.23	30.55	33.08
Cr ₂ O ₃	0.00	0.00	0.02	0.04	0.02	0.02	0.00	0.02	0.04	0.05	0.05	0.08
Bi ₂ O ₃												
Fe ₂ O ₃ *	0.00	0.00	0.00	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.62	0.00
FeO*	10.12	8.59	8.35	9.73	11.62	9.29	9.81	11.36	11.81	8.64	9.26	8.22
FeO (tot)	10.12	8.59	8.35	10.06	11.62	9.29	9.81	11.36	11.81	8.64	9.82	8.22
MnO	0.09	0.09	0.05	0.15	0.32	0.19	0.16	0.30	0.60	0.39	0.26	0.26
ZnO	0.00	0.03	0.05	0.13	0.12	0.01	0.01	0.10	0.04	0.00	0.04	0.09
MgO	5.13	5.50	5.57	4.64	3.20	5.08	4.47	3.27	2.44	5.96	6.28	5.93
Li 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
CaO	0.53	0.57	0.63	0.26	0.19	0.41	0.31	0.34	0.34	0.82	0.89	0.51
Na ₂ O	1.84	1.74	1.87	1.82	1.94	1.98	1.89	2.00	1.99	1.88	1.94	2.05
K ₂ O	0.05	0.05	0.06	0.04	0.05	0.03	0.03	0.06	0.05	0.04	0.03	0.02
F	0.22	0.19	0.23	0.24	0.12	0.44	0.36	0.32	0.42	0.42	0.58	0.45
Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00
H ₂ O*	3.45	3.42	3.34	3.49	3.41	3.28	3.28	3.31	3.16	3.32	3.29	3.34
-(O=F,Cl)	-0.09	-0.08	-0.10	-0.10	-0.05	-0.19	-0.15	-0.14	-0.18	-0.17	-0.25	-0.19
Total	99.83	100.12	99.94	100.00	99.67	99.09	98.79	99.55	99.53	99.59	99.60	99.91
T Si (apfu)	5.900	5.867	5.834	5.814	5.875	5.844	5.839	5.697	5.699	5.843	5.861	5.827
T Al	0.100	0.133	0.166	0.186	0.125	0.156	0.161	0.303	0.301	0.157	0.139	0.173
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	5.904	6.000
Y Ti	0.053	0.053	0.063	0.041	0.016	0.059	0.078	0.097	0.096	0.071	0.097	0.052
Y Al	0.247	0.390	0.389	0.366	0.484	0.337	0.393	0.419	0.519	0.180	0.000	0.287
Y Cr	0.000	0.000	0.003	0.006	0.003	0.003	0.000	0.002	0.005	0.006	0.007	0.010
Y Fe ³⁺	0.000	0.000	0.000	0.046	0.000	0.000	0.000	0.000	0.000	0.000	0.078	0.000
Y Fe ²⁺	1.411	1.186	1.157	1.353	1.635	1.303	1.381	1.603	1.673	1.205	1.300	1.140
Y Mn	0.013	0.013	0.007	0.021	0.046	0.028	0.023	0.043	0.086	0.055	0.037	0.036
Y Zn	0.000	0.004	0.006	0.016	0.015	0.001	0.001	0.013	0.005	0.000	0.005	0.011
Y Mg	1.276	1.355	1.375	1.150	0.802	1.269	1.123	0.823	0.616	1.482	1.571	1.465
Y Li	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
X Ca	0.095	0.101	0.112	0.046	0.035	0.073	0.055	0.061	0.061	0.147	0.159	0.091
X Na	0.596	0.556	0.601	0.586	0.633	0.644	0.616	0.656	0.653	0.609	0.631	0.659
x K	0.010	0.011	0.012	0.009	0.011	0.007	0.006	0.013	0.011	0.009	0.007	0.005
X vac	0.299	0.333	0.275	0.360	0.321	0.275	0.323	0.270	0.274	0.236	0.203	0.245
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.115	0.101	0.120	0.124	0.065	0.235	0.194	0.173	0.226	0.219	0.310	0.236
W Cl	0.000	0.001	0.001	0.000	0.000	0.000	0.001	0.001	0.003	0.000	0.003	0.000
W OH	0.835	0.766	0.690	0.876	0.827	0.666	0.684	0.724	0.569	0.698	0.687	0.691
W O	0.050	0.132	0.189	0.000	0.108	0.099	0.121	0.102	0.202	0.083	0.000	0.073
Classif.	schorl	dravite	dravite	schorl	schorl	schorl	schorl	schorl	schorl	dravite	dravite	dravite

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site	01	GARPHOS-S01-1										
Comments	border zone tur	unbleached dark blue tur core	blue tur core	edge of blue core before dark green zone	dark green zone	medium green zone	light green zone	skinny blue zone	yellow zone	yellow zone? Medium gray on BSE	yellow zone? Dark medium gray on BSE	yellow zone? Darker medium gray on BSE (absolute rim of main xtl)
Point	47t-2	GP1-1	GP1-2	GP1-3	GP1-4	GP1-5	GP1-6	GP1-7	GP1-8	GP1-9	GP1-10	GP1-12
SiO ₂ (wt.%)	35.57	34.10	33.54	34.00	33.24	33.47	33.19	33.49	33.37	34.20	33.54	35.15
TiO ₂	0.42	0.26	0.27	0.25	0.55	0.51	0.50	0.44	0.17	0.36	0.36	0.23
B ₂ O ₃ *	10.49	10.28	10.25	10.29	10.25	10.37	10.28	10.39	10.38	10.58	10.53	10.72
Al ₂ O ₃	33.12	34.92	35.28	35.34	35.50	36.26	36.14	36.94	37.75	38.71	38.96	39.51
Cr ₂ O ₃	0.06	0.00	0.03	0.00	0.03	0.00	0.01	0.00	0.00	0.04	0.00	0.02
Bi ₂ O ₃												
Fe ₂ O ₃ *	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO*	7.95	12.75	12.71	12.52	11.96	11.67	11.08	10.57	8.87	5.06	5.96	3.59
FeO (tot)	7.95	12.75	12.71	12.52	11.96	11.67	11.08	10.57	8.87	5.06	5.96	3.59
MnO	0.26	1.43	1.38	1.41	1.51	1.88	1.86	1.93	2.47	3.31	2.98	3.00
ZnO	0.05	0.17	0.24	0.21	0.26	0.24	0.45	0.42	0.36	0.13	0.13	0.01
MgO	5.80	0.38	0.38	0.33	0.33	0.26	0.18	0.11	0.05	0.10	0.09	0.15
Li ₂ O*	0.00	0.17	0.13	0.15	0.25	0.25	0.28	0.34	0.44	0.97	0.84	1.19
CaO	0.49	0.03	0.03	0.02	0.05	0.07	0.07	0.08	0.08	0.13	0.14	0.09
Na ₂ O	2.08	1.63	1.72	1.52	1.94	1.90	1.87	1.83	1.84	2.42	2.37	2.32
K ₂ O	0.03	0.04	0.04	0.03	0.02	0.05	0.03	0.03	0.04	0.02	0.02	0.01
F	0.42	0.26	0.27	0.56	0.28	0.46	0.54	0.57	0.77	1.17	1.01	1.31
Cl	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H ₂ O*	3.22	3.42	3.41	3.28	3.40	3.36	3.29	3.32	3.22	3.09	3.15	3.08
-(O=F,Cl)	-0.18	-0.11	-0.11	-0.24	-0.12	-0.19	-0.23	-0.24	-0.32	-0.49	-0.43	-0.55
Total	99.79	99.73	99.55	99.69	99.46	100.55	99.56	100.22	99.48	99.81	99.66	99.83
T Si (apfu)	5.893	5.767	5.689	5.745	5.635	5.611	5.610	5.602	5.586	5.617	5.537	5.701
T Al	0.107	0.233	0.311	0.255	0.365	0.389	0.390	0.398	0.414	0.383	0.463	0.299
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.052	0.033	0.034	0.032	0.070	0.065	0.063	0.055	0.021	0.045	0.045	0.028
Y Al	0.362	0.727	0.744	0.783	0.728	0.773	0.808	0.885	1.034	1.111	1.119	1.254
Y Cr	0.008	0.000	0.005	0.000	0.005	0.000	0.001	0.000	0.000	0.005	0.000	0.003
Y Fe ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y Fe ²⁺	1.102	1.804	1.804	1.769	1.695	1.635	1.567	1.478	1.241	0.695	0.823	0.487
Y Mn	0.036	0.205	0.198	0.202	0.216	0.267	0.267	0.274	0.350	0.461	0.417	0.412
Y Zn	0.006	0.021	0.030	0.027	0.033	0.029	0.056	0.051	0.044	0.016	0.016	0.001
Y Mg	1.434	0.096	0.095	0.083	0.083	0.064	0.046	0.028	0.012	0.025	0.022	0.037
Y Li	0.000	0.114	0.091	0.105	0.170	0.167	0.193	0.229	0.297	0.643	0.559	0.778
X Ca	0.087	0.005	0.005	0.003	0.010	0.013	0.013	0.015	0.015	0.022	0.025	0.016
X Na	0.668	0.534	0.565	0.499	0.637	0.617	0.614	0.595	0.598	0.771	0.758	0.731
x K	0.007	0.008	0.009	0.007	0.005	0.012	0.006	0.007	0.008	0.005	0.005	0.002
X vac	0.238	0.452	0.421	0.490	0.349	0.359	0.366	0.383	0.380	0.201	0.212	0.252
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.221	0.141	0.146	0.300	0.153	0.242	0.288	0.300	0.407	0.610	0.529	0.670
W Cl	0.001	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000
W OH	0.562	0.859	0.854	0.700	0.847	0.758	0.711	0.700	0.593	0.390	0.470	0.330
W O	0.216	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Classif.	dravite	schorl	schorl	schorl	schorl	schorl	schorl	schorl	schorl	fluor-elbaite	fluor-schorl	fluor-elbaite

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site												
Comments	clear skeletal tur closest to main xtl	clear skeletal tur middle distance to main xtl	clear skeletal tur core farthest from main xtl	yellow tourmaline in big fracture of main xtl	yellow tourmaline in big fracture of main xtl	yellow tourmaline core at bottom of main xtl	yellow tourmaline core at bottom of main xtl	yellow tourmaline rim at bottom of main xtl	yellow tourmaline rim at bottom of main xtl	bleached fracture in blue core of main xtl	unbleached fracture in blue core of main xtl	unbleached fracture in blue-brown zone of main xtl
Point	GP1-13	GP1-14	GP1-15	GP1-16	GP1-17	GP1-18	GP1-19	GP1-20	GP1-21	GP1-22	GP1-23	GP1-24
SiO ₂ (wt.%)	35.13	34.73	35.31	35.16	34.78	35.18	35.16	35.68	35.97	33.81	34.16	33.73
TiO ₂	0.34	0.16	0.31	0.32	0.46	0.29	0.35	0.25	0.19	0.29	0.23	0.34
B ₂ O ₃ *	10.74	10.53	10.70	10.52	10.46	10.75	10.77	10.75	10.72	10.29	10.31	10.27
Al ₂ O ₃	39.48	38.24	38.88	36.88	36.30	39.66	39.63	39.42	38.88	35.53	35.62	35.45
Cr ₂ O ₃	0.01	0.00	0.03	0.01	0.01	0.00	0.00	0.00	0.04	0.00	0.00	0.05
Bi ₂ O ₃												
Fe ₂ O ₃ *	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO*	3.24	4.38	3.91	6.74	9.00	3.30	3.00	0.91	1.20	11.92	11.57	11.79
FeO (tot)	3.24	4.38	3.91	6.74	9.00	3.30	3.00	0.91	1.20	11.92	11.57	11.79
MnO	3.23	3.64	2.66	1.97	0.80	3.13	3.62	4.57	4.32	1.66	1.71	1.64
ZnO	0.09	0.02	0.00	0.05	0.10	0.12	0.00	0.00	0.02	0.28	0.20	0.27
MgO	0.11	0.19	0.23	0.21	0.33	0.13	0.07	0.04	0.01	0.29	0.31	0.26
Li ₂ O*	1.27	0.97	1.26	1.06	0.91	1.22	1.28	1.44	1.45	0.22	0.24	0.24
CaO	0.09	0.02	0.07	0.02	0.02	0.05	0.06	0.06	0.03	0.03	0.04	0.04
Na ₂ O	2.58	2.13	2.54	2.54	2.55	2.44	2.68	2.58	2.50	1.72	1.51	1.71
K ₂ O	0.01	0.02	0.01	0.02	0.03	0.02	0.02	0.01	0.04	0.03	0.03	0.03
F	1.40	1.27	1.13	1.51	1.51	1.30	1.37	1.52	1.59	0.28	0.49	0.37
Cl	0.02	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
H ₂ O*	3.04	3.03	3.15	2.92	2.90	3.09	3.06	2.99	2.94	3.42	3.33	3.37
-(O=F,Cl)	-0.59	-0.54	-0.48	-0.63	-0.63	-0.55	-0.58	-0.64	-0.67	-0.12	-0.21	-0.16
Total	100.18	98.80	99.72	99.30	99.50	100.12	100.50	99.57	99.24	99.64	99.54	99.40
T Si (apfu)	5.685	5.734	5.737	5.808	5.776	5.690	5.673	5.767	5.831	5.711	5.757	5.709
T Al	0.315	0.266	0.263	0.192	0.224	0.310	0.327	0.233	0.169	0.289	0.243	0.291
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.041	0.020	0.038	0.040	0.057	0.035	0.043	0.030	0.023	0.037	0.029	0.043
Y Al	1.215	1.174	1.181	0.990	0.881	1.250	1.209	1.276	1.262	0.784	0.833	0.781
Y Cr	0.002	0.000	0.003	0.001	0.002	0.000	0.000	0.000	0.005	0.000	0.000	0.007
Y Fe ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y Fe ²⁺	0.439	0.605	0.532	0.931	1.250	0.447	0.405	0.123	0.163	1.684	1.631	1.670
Y Mn	0.443	0.509	0.365	0.276	0.112	0.429	0.495	0.626	0.594	0.237	0.244	0.235
Y Zn	0.010	0.003	0.000	0.007	0.012	0.014	0.000	0.000	0.002	0.035	0.025	0.034
Y Mg	0.026	0.046	0.056	0.051	0.082	0.030	0.018	0.009	0.003	0.072	0.078	0.065
Y Li	0.823	0.644	0.824	0.705	0.605	0.794	0.831	0.935	0.948	0.151	0.160	0.166
X Ca	0.015	0.004	0.012	0.004	0.003	0.008	0.011	0.011	0.006	0.006	0.007	0.007
X Na	0.809	0.683	0.800	0.814	0.820	0.764	0.837	0.807	0.784	0.563	0.493	0.563
x K	0.001	0.004	0.002	0.003	0.007	0.003	0.005	0.002	0.007	0.007	0.007	0.007
X vac	0.175	0.309	0.186	0.178	0.171	0.224	0.147	0.180	0.203	0.424	0.493	0.424
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.718	0.665	0.583	0.787	0.791	0.664	0.701	0.776	0.817	0.148	0.262	0.199
W Cl	0.004	0.000	0.001	0.000	0.000	0.001	0.001	0.000	0.001	0.000	0.000	0.001
W OH	0.278	0.335	0.416	0.213	0.209	0.335	0.298	0.224	0.182	0.852	0.738	0.801
W O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Classif.	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-schorl	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite	schorl	schorl	schorl

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site	GARPHOS-S01-2											
Comments	bleached fracture in blue-brown zone of main xtl	unbleached fracture in dark green zone of main xtl	bleached fracture in dark green zone of main xtl	blue-brown triangular core in main xtl	blue-brown triangular core in main xtl	blue-brown triangular core in main xtl	unbleached dark blue tur core	bleached dark blue tur core	bleached dark blue tur core	unaltered tur near rim of main xtl	dissolution tur near rim of main xtl	dissolution tur in rim of main xtl
Point	GP1-25	GP1-26	GP1-27	GP1-28	GP1-29	GP1-30	GP1-31	GP1-32	GP1-33	GP2-1	GP2-2	GP2-3
SiO ₂ (wt.%)	33.81	34.05	33.29	33.50	33.74	33.43	34.02	33.88	34.12	33.61	35.12	35.73
TiO ₂	0.36	0.37	0.44	0.40	0.34	0.43	0.18	0.27	0.31	0.40	0.30	0.23
B ₂ O ₃ *	10.29	10.34	10.19	10.17	10.27	10.25	10.34	10.25	10.30	10.29	10.47	10.61
Al ₂ O ₃	35.57	35.76	35.49	34.85	34.97	35.28	35.64	35.17	35.19	35.54	36.19	37.94
Cr ₂ O ₃	0.03	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.05	0.00	0.03
Bi ₂ O ₃												
Fe ₂ O ₃ *	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO*	11.72	11.40	11.01	12.43	13.23	12.91	12.56	12.66	12.44	12.04	8.00	4.08
FeO (tot)	11.72	11.40	11.01	12.43	13.23	12.91	12.56	12.66	12.44	12.04	8.00	4.08
MnO	1.75	1.81	1.88	1.34	1.10	1.24	1.43	1.42	1.33	1.66	1.08	2.05
ZnO	0.19	0.33	0.28	0.18	0.18	0.21	0.20	0.15	0.29	0.23	0.22	0.02
MgO	0.25	0.23	0.18	0.37	0.43	0.38	0.35	0.33	0.33	0.30	0.19	0.12
Li ₂ O*	0.23	0.27	0.31	0.18	0.15	0.14	0.16	0.13	0.20	0.21	1.07	1.40
CaO	0.02	0.05	0.05	0.05	0.04	0.04	0.03	0.04	0.02	0.04	0.03	0.04
Na ₂ O	1.66	1.64	1.76	1.62	1.82	1.75	1.67	1.46	1.61	1.76	2.75	2.58
K ₂ O	0.02	0.02	0.04	0.02	0.02	0.04	0.04	0.03	0.04	0.04	0.04	0.02
F	0.34	0.47	0.49	0.47	0.32	0.26	0.39	0.45	0.46	0.63	1.77	1.54
Cl	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H ₂ O*	3.39	3.34	3.29	3.29	3.39	3.41	3.38	3.32	3.33	3.25	2.77	2.93
-(O=F,Cl)	-0.14	-0.20	-0.20	-0.20	-0.14	-0.11	-0.16	-0.19	-0.20	-0.27	-0.74	-0.65
Total	99.50	99.90	98.48	98.66	99.87	99.67	100.24	99.37	99.80	99.77	99.26	98.66
T Si (apfu)	5.713	5.724	5.678	5.722	5.712	5.669	5.720	5.746	5.758	5.679	5.830	5.851
T Al	0.287	0.276	0.322	0.278	0.288	0.331	0.280	0.254	0.242	0.321	0.170	0.149
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.046	0.047	0.056	0.051	0.044	0.054	0.023	0.035	0.040	0.050	0.037	0.029
Y Al	0.796	0.809	0.811	0.740	0.690	0.718	0.782	0.774	0.756	0.756	0.910	1.173
Y Cr	0.005	0.000	0.001	0.000	0.000	0.000	0.001	0.000	0.000	0.007	0.000	0.003
Y Fe ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y Fe ²⁺	1.656	1.603	1.570	1.776	1.873	1.831	1.767	1.795	1.756	1.701	1.111	0.558
Y Mn	0.251	0.258	0.271	0.194	0.158	0.179	0.204	0.203	0.191	0.237	0.151	0.284
Y Zn	0.024	0.041	0.035	0.022	0.023	0.026	0.025	0.019	0.036	0.029	0.027	0.002
Y Mg	0.064	0.057	0.046	0.094	0.109	0.095	0.087	0.082	0.084	0.076	0.047	0.028
Y Li	0.159	0.185	0.210	0.123	0.104	0.097	0.111	0.091	0.137	0.143	0.717	0.922
X Ca	0.004	0.009	0.009	0.009	0.006	0.008	0.005	0.008	0.004	0.007	0.005	0.007
X Na	0.542	0.536	0.583	0.538	0.597	0.575	0.543	0.481	0.526	0.577	0.885	0.818
x K	0.005	0.004	0.008	0.004	0.004	0.010	0.008	0.006	0.009	0.009	0.009	0.005
X vac	0.449	0.450	0.400	0.450	0.393	0.407	0.443	0.506	0.461	0.407	0.101	0.170
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.181	0.251	0.262	0.255	0.173	0.141	0.206	0.243	0.247	0.337	0.929	0.796
W Cl	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000
W OH	0.817	0.749	0.738	0.745	0.827	0.859	0.794	0.757	0.753	0.663	0.071	0.204
W O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Classif.	schorl	schorl	schorl	schorl	schorl	schorl	schorl	foitite	schorl	schorl	fluor-elbaite	fluor-elbaite

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site												
Comments	unaltered tur in rim of main xtl	skeletal overgrowth rim	skeletal overgrowth core	skeletal overgrowth core	skeletal overgrowth intermediate between dark and "regular" cores	skeletal overgrowth intermediate between dark and "regular" cores	skeletal overgrowth dark core	skeletal overgrowth dark core	skeletal overgrowth rim of dark core	skeletal overgrowth rim of dark core	center of largely homogeneous main xtl	center of largely homogeneous main xtl
Point	GP2-4	GP2-5	GP2-7	GP2-8	GP2-9	GP2-10	GP2-11	GP2-12	GP2-13	GP2-14	GP2-15	GP2-16
SiO ₂ (wt.%)	34.83	35.92	34.42	33.51	34.32	34.25	35.01	35.04	36.19	36.16	33.53	35.34
TiO ₂	0.17	0.22	0.14	0.27	0.34	0.23	0.25	0.18	0.17	0.24	0.37	0.30
B ₂ O ₃ *	10.68	10.66	10.45	10.51	10.62	10.58	10.56	10.60	10.75	10.72	10.12	10.43
Al ₂ O ₃	39.21	38.20	37.68	39.01	39.71	39.57	37.90	38.00	39.00	38.46	33.66	34.98
Cr ₂ O ₃	0.03	0.01	0.02	0.02	0.00	0.03	0.04	0.02	0.03	0.00	0.00	0.05
Bi ₂ O ₃												
Fe ₂ O ₃ *	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO*	3.92	2.09	5.61	5.86	2.83	2.69	4.38	5.84	1.00	2.10	14.05	9.61
FeO (tot)	3.92	2.09	5.61	5.86	2.83	2.69	4.38	5.84	1.00	2.10	14.05	9.61
MnO	4.05	3.77	3.36	3.34	3.36	3.38	2.70	1.98	4.39	3.56	1.03	0.71
ZnO	0.18	0.04	0.19	0.26	0.00	0.00	0.04	0.11	0.00	0.02	0.09	0.15
MgO	0.06	0.05	0.02	0.01	0.08	0.10	0.07	0.15	0.02	0.06	0.68	0.42
Li ₂ O*	1.01	1.46	0.87	0.77	1.23	1.23	1.29	1.16	1.46	1.49	0.04	0.94
CaO	0.08	0.03	0.08	0.14	0.10	0.09	0.06	0.07	0.02	0.04	0.07	0.01
Na ₂ O	2.34	2.68	2.06	2.22	2.51	2.52	2.78	2.70	2.42	2.63	1.70	2.72
K ₂ O	0.00	0.00	0.04	0.02	0.02	0.03	0.02	0.04	0.04	0.02	0.05	0.03
F	1.23	1.56	0.76	0.77	1.28	1.45	1.60	1.74	1.48	1.49	0.34	1.49
Cl	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.01	0.00
H ₂ O*	3.10	2.94	3.24	3.26	3.06	2.96	2.89	2.83	3.01	2.99	3.33	2.89
-(O=F,Cl)	-0.52	-0.66	-0.32	-0.33	-0.54	-0.61	-0.67	-0.73	-0.62	-0.63	-0.15	-0.63
Total	100.37	98.96	98.63	99.65	98.90	98.51	98.91	99.75	99.35	99.36	98.91	99.44
T Si (apfu)	5.667	5.854	5.727	5.539	5.617	5.626	5.761	5.743	5.851	5.861	5.758	5.891
T Al	0.333	0.146	0.273	0.461	0.383	0.374	0.239	0.257	0.149	0.139	0.242	0.109
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.021	0.027	0.018	0.033	0.042	0.028	0.031	0.023	0.020	0.029	0.048	0.038
Y Al	1.185	1.192	1.114	1.139	1.277	1.288	1.110	1.083	1.283	1.208	0.572	0.764
Y Cr	0.003	0.001	0.003	0.002	0.000	0.003	0.006	0.003	0.004	0.000	0.000	0.006
Y Fe ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y Fe ²⁺	0.534	0.285	0.780	0.810	0.387	0.370	0.602	0.800	0.136	0.284	2.017	1.340
Y Mn	0.559	0.521	0.473	0.468	0.465	0.471	0.376	0.275	0.601	0.488	0.151	0.101
Y Zn	0.022	0.004	0.023	0.031	0.000	0.000	0.005	0.013	0.000	0.003	0.012	0.018
Y Mg	0.013	0.012	0.004	0.003	0.020	0.026	0.018	0.036	0.006	0.014	0.175	0.105
Y Li	0.663	0.958	0.584	0.514	0.810	0.814	0.851	0.766	0.952	0.974	0.026	0.628
X Ca	0.014	0.005	0.015	0.025	0.017	0.016	0.011	0.012	0.004	0.007	0.013	0.002
X Na	0.738	0.846	0.665	0.713	0.795	0.802	0.886	0.859	0.757	0.827	0.564	0.880
x K	0.001	0.001	0.008	0.005	0.005	0.006	0.005	0.009	0.008	0.005	0.010	0.006
X vac	0.247	0.148	0.312	0.258	0.183	0.176	0.099	0.120	0.230	0.161	0.413	0.112
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.634	0.805	0.398	0.405	0.662	0.754	0.832	0.903	0.755	0.764	0.186	0.787
W Cl	0.000	0.000	0.004	0.001	0.001	0.002	0.000	0.000	0.002	0.000	0.002	0.000
W OH	0.366	0.195	0.598	0.594	0.337	0.244	0.168	0.097	0.243	0.236	0.813	0.213
W O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Classif.	fluor-elbaite	fluor-elbaite	schorl	schorl	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite	schorl	fluor-schorl

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site												
Comments	slightly left of center of largely homogeneous main xtl	even more left of center of largely homogeneous xtl	dark dissolution feature at left upper edge in the largely homogeneous main xtl	unperturbed tur at upper left edge of the main xtl	small zoned tur xtl on extreme right: rim	small zoned tur xtl on extreme right: rim	small zoned tur xtl on extreme right: core	small zoned tur xtl on extreme right: core	small zoned tur xtl in center: core	small zoned tur xtl in center: core	small zoned tur xtl in center: rim	small zoned tur xtl in center: rim
Point	GP2-17	GP2-18	GP2-19	GP2-20	GP2-21	GP2-22	GP2-23	GP2-24	GP2-25	GP2-26	GP2-27	GP2-28
SiO ₂ (wt.%)	34.01	33.40	34.88	33.14	35.12	34.97	34.67	35.45	35.19	35.13	35.70	35.35
TiO ₂	0.37	0.38	0.38	0.66	0.22	0.27	0.20	0.11	0.19	0.24	0.26	0.26
B ₂ O ₃ *	10.24	10.10	10.33	10.05	10.61	10.63	10.59	10.66	10.67	10.65	10.73	10.74
Al ₂ O ₃	33.91	33.52	35.07	33.04	38.40	38.95	38.62	38.70	38.78	38.55	39.03	39.73
Cr ₂ O ₃	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.01	0.01
Bi ₂ O ₃												
Fe ₂ O ₃ *	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO*	14.08	13.76	8.80	13.57	3.62	3.79	4.20	3.61	3.96	3.88	1.92	0.90
FeO (tot)	14.08	13.76	8.80	13.57	3.62	3.79	4.20	3.61	3.96	3.88	1.92	0.90
MnO	0.90	0.63	0.66	0.76	2.76	2.77	3.81	3.83	3.87	4.03	3.72	4.17
ZnO	0.02	0.11	0.05	0.00	0.00	0.04	0.04	0.05	0.00	0.05	0.01	0.05
MgO	0.82	1.04	0.40	1.05	0.21	0.19	0.14	0.08	0.09	0.14	0.05	0.04
Li ₂ O*	0.09	0.07	1.01	0.15	1.34	1.19	1.02	1.11	1.07	1.04	1.47	1.48
CaO	0.08	0.08	0.00	0.14	0.08	0.10	0.03	0.04	0.03	0.03	0.05	0.05
Na ₂ O	1.85	1.84	2.70	1.98	2.77	2.31	2.39	2.20	2.29	2.28	2.75	2.72
K ₂ O	0.02	0.01	0.03	0.05	0.01	0.04	0.02	0.01	0.01	0.03	0.02	0.02
F	0.24	0.22	1.72	0.34	1.35	1.28	0.90	1.03	1.15	0.91	1.48	1.44
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
H ₂ O*	3.42	3.38	2.75	3.31	3.02	3.06	3.23	3.19	3.13	3.24	3.00	3.02
-(O=F,Cl)	-0.10	-0.09	-0.72	-0.14	-0.57	-0.54	-0.38	-0.44	-0.49	-0.39	-0.63	-0.61
Total	99.96	98.47	98.05	98.10	98.95	99.06	99.48	99.65	99.97	99.83	99.58	99.39
T Si (apfu)	5.771	5.748	5.871	5.732	5.752	5.719	5.689	5.778	5.734	5.735	5.780	5.721
T Al	0.229	0.252	0.129	0.268	0.248	0.281	0.311	0.222	0.266	0.265	0.220	0.279
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.047	0.050	0.048	0.086	0.027	0.034	0.024	0.013	0.024	0.030	0.032	0.032
Y Al	0.554	0.547	0.828	0.467	1.163	1.226	1.159	1.211	1.180	1.154	1.228	1.298
Y Cr	0.000	0.004	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.002	0.001	0.002
Y Fe ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y Fe ²⁺	1.999	1.981	1.239	1.963	0.496	0.519	0.577	0.493	0.539	0.530	0.261	0.121
Y Mn	0.129	0.092	0.095	0.112	0.383	0.384	0.530	0.529	0.534	0.558	0.510	0.572
Y Zn	0.003	0.013	0.007	0.000	0.000	0.005	0.005	0.006	0.000	0.007	0.001	0.006
Y Mg	0.207	0.268	0.100	0.271	0.052	0.046	0.033	0.020	0.022	0.034	0.013	0.009
Y Li	0.062	0.045	0.685	0.101	0.879	0.786	0.672	0.728	0.698	0.686	0.955	0.960
X Ca	0.015	0.015	0.001	0.027	0.014	0.017	0.005	0.008	0.005	0.005	0.008	0.009
X Na	0.607	0.613	0.882	0.665	0.879	0.731	0.760	0.695	0.722	0.720	0.863	0.853
x K	0.004	0.003	0.007	0.012	0.003	0.008	0.004	0.002	0.002	0.005	0.004	0.004
X vac	0.373	0.369	0.110	0.296	0.104	0.244	0.230	0.295	0.271	0.270	0.125	0.134
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.126	0.119	0.913	0.184	0.701	0.663	0.468	0.533	0.595	0.472	0.760	0.737
W Cl	0.001	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.001	0.000
W OH	0.873	0.881	0.087	0.816	0.299	0.335	0.532	0.467	0.405	0.528	0.238	0.263
W O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Classif.	schorl	schorl	fluor-schorl	schorl	fluor-elbaite	fluor-elbaite	elbaite	fluor-elbaite	fluor-elbaite	elbaite	fluor-elbaite	fluor-elbaite

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site	GARPHOS-S01-3											
Comments	tiny skeletal overgrowth feature on main xtl	blue core of main xtl	brown core of main xtl	dark green rim of main xtl	light green rim of main xtl; light in BSE	light green rim of main xtl; medium in BSE	light green rim of main xtl; dark in BSE	medium green in rabbit-eared tur ("head")	medium green in rabbit-eared tur ("head")	dark green in rabbit-eared tur ("head")	dark green in rabbit-eared tur (top "ear")	yellowish in rabbit-eared tur (bottom "ear")
Point	GP2-31	GP3-1	GP3-2	GP3-3	GP3-4	GP3-5	GP3-6	GP3-7	GP3-8	GP3-9	GP3-10	GP3-11
SiO ₂ (wt.%)	35.29	36.42	36.12	35.42	34.25	35.65	35.70	34.49	34.51	33.83	33.92	35.26
TiO ₂	0.24	0.28	0.50	0.62	0.65	0.43	0.24	0.64	0.42	0.61	0.52	0.43
B ₂ O ₃ *	10.56	10.57	10.55	10.49	10.25	10.70	10.76	10.51	10.46	10.16	10.17	10.54
Al ₂ O ₃	37.76	33.11	33.04	32.91	33.09	37.16	38.50	35.90	35.82	33.05	33.04	35.68
Cr ₂ O ₃	0.06	0.02	0.00	0.04	0.00	0.00	0.03	0.01	0.02	0.00	0.06	0.02
Bi ₂ O ₃												
Fe ₂ O ₃ *	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO*	3.74	10.37	9.84	12.04	13.01	7.90	5.83	10.08	10.75	14.37	14.61	9.46
FeO (tot)	3.74	10.37	9.84	12.04	13.01	7.90	5.83	10.08	10.75	14.37	14.61	9.46
MnO	2.93	0.12	0.16	0.23	0.29	1.12	0.99	1.64	1.61	0.99	0.99	0.99
ZnO	0.03	0.02	0.00	0.08	0.02	0.06	0.02	0.16	0.14	0.16	0.12	0.05
MgO	0.11	4.16	4.50	3.37	2.08	1.14	0.64	0.99	0.94	0.73	0.77	0.69
Li ₂ O*	1.32	0.15	0.13	0.12	0.12	0.82	1.21	0.49	0.35	0.09	0.05	0.86
CaO	0.03	0.21	0.31	0.31	0.17	0.15	0.30	0.11	0.09	0.13	0.12	0.09
Na ₂ O	2.65	1.77	1.65	1.97	1.87	2.17	2.39	2.21	1.90	1.79	1.80	2.66
K ₂ O	0.02	0.03	0.04	0.05	0.04	0.00	0.03	0.04	0.01	0.06	0.05	0.04
F	1.79	0.13	0.34	0.02	0.19	1.01	1.55	0.65	0.59	0.28	0.35	1.31
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
H ₂ O*	2.79	3.59	3.48	3.61	3.44	3.21	2.98	3.32	3.33	3.37	3.34	3.01
-(O=F,Cl)	-0.75	-0.05	-0.14	-0.01	-0.08	-0.42	-0.65	-0.27	-0.25	-0.12	-0.15	-0.55
Total	98.56	100.89	100.52	101.25	99.41	101.11	100.52	100.96	100.70	99.51	99.77	100.53
T Si (apfu)	5.809	5.985	5.951	5.870	5.808	5.789	5.768	5.705	5.732	5.790	5.795	5.817
T Al	0.191	0.015	0.049	0.130	0.192	0.211	0.232	0.295	0.268	0.210	0.205	0.183
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.030	0.035	0.062	0.077	0.083	0.052	0.029	0.079	0.052	0.079	0.067	0.054
Y Al	1.136	0.400	0.367	0.297	0.421	0.902	1.100	0.705	0.745	0.455	0.448	0.753
Y Cr	0.008	0.003	0.000	0.006	0.000	0.001	0.003	0.001	0.003	0.000	0.009	0.003
Y Fe ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y Fe ²⁺	0.515	1.425	1.356	1.668	1.845	1.073	0.787	1.394	1.494	2.057	2.087	1.304
Y Mn	0.409	0.017	0.022	0.032	0.041	0.154	0.136	0.230	0.227	0.144	0.143	0.138
Y Zn	0.004	0.002	0.001	0.010	0.002	0.007	0.002	0.019	0.017	0.021	0.015	0.006
Y Mg	0.026	1.020	1.104	0.833	0.527	0.277	0.154	0.245	0.232	0.185	0.196	0.171
Y Li	0.872	0.099	0.088	0.078	0.081	0.534	0.789	0.326	0.231	0.059	0.035	0.571
X Ca	0.006	0.037	0.054	0.054	0.031	0.027	0.053	0.019	0.017	0.024	0.023	0.017
X Na	0.844	0.563	0.527	0.633	0.614	0.684	0.747	0.710	0.610	0.594	0.595	0.850
x K	0.004	0.005	0.009	0.011	0.009	0.000	0.006	0.009	0.002	0.012	0.010	0.007
X vac	0.146	0.395	0.409	0.302	0.346	0.289	0.194	0.262	0.371	0.369	0.373	0.126
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.931	0.067	0.175	0.012	0.104	0.518	0.792	0.339	0.308	0.152	0.188	0.685
W Cl	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W OH	0.067	0.933	0.825	0.988	0.896	0.482	0.208	0.661	0.692	0.848	0.812	0.315
W O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Classif.	fluor-elbaite	schorl	schorl	schorl	schorl	fluor-schorl	fluor-elbaite	schorl	schorl	schorl	schorl	fluor-schorl

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site												
Comments	yellowish in rabbit-eared tur (bottom "ear")	small middle tur core	small middle tur core	small middle tur rim	bigger middle tur core	bigger middle tur core	bigger middle tur rim	bigger middle tur rim	tiny bottom tur core	tiny bottom tur core	tiny bottom tur intermediate	tiny bottom tur intermediate
Point	GP3-12	GP3-13	GP3-14	GP3-15	GP3-17	GP3-18	GP3-19	GP3-20	GP3-21	GP3-22	GP3-23	GP3-24
SiO ₂ (wt.%)	35.35	36.24	35.57	35.91	35.52	36.00	35.79	35.59	34.76	35.33	35.41	35.60
TiO ₂	0.49	0.32	0.32	0.29	0.25	0.24	0.39	0.26	0.33	0.35	0.34	0.42
B ₂ O ₃ *	10.46	10.87	10.86	10.71	10.74	10.78	10.79	10.74	10.65	10.73	10.74	10.79
Al ₂ O ₃	35.17	39.09	39.67	38.14	38.70	38.26	38.88	38.74	38.91	38.81	38.60	38.95
Cr ₂ O ₃	0.03	0.03	0.00	0.00	0.04	0.03	0.00	0.03	0.02	0.04	0.00	0.02
Bi ₂ O ₃												
Fe ₂ O ₃ *	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO*	9.22	3.85	3.88	3.08	4.53	5.17	3.98	4.47	4.52	4.30	4.28	4.42
FeO (tot)	9.22	3.85	3.88	3.08	4.53	5.17	3.98	4.47	4.52	4.30	4.28	4.42
MnO	0.84	2.85	2.89	3.43	3.83	3.65	2.80	2.49	2.67	2.67	2.78	2.43
ZnO	0.04	0.06	0.00	0.01	0.08	0.06	0.00	0.02	0.04	0.00	0.08	0.04
MgO	0.62	0.18	0.15	0.15	0.15	0.21	0.21	0.15	0.17	0.16	0.17	0.22
Li ₂ O*	0.92	1.32	1.29	1.41	1.00	0.99	1.30	1.28	1.18	1.27	1.31	1.29
CaO	0.04	0.09	0.09	0.06	0.02	0.04	0.08	0.04	0.09	0.08	0.15	0.06
Na ₂ O	2.58	2.50	2.71	2.81	2.20	2.18	2.59	2.69	2.63	2.70	2.80	2.71
K ₂ O	0.04	0.02	0.02	0.02	0.02	0.02	0.03	0.01	0.00	0.03	0.03	0.03
F	1.61	1.27	1.14	1.71	0.99	1.20	1.13	1.41	1.34	1.41	1.47	1.29
Cl	0.03	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00
H ₂ O*	2.84	3.15	3.21	2.88	3.23	3.15	3.19	3.04	3.04	3.03	3.01	3.11
-(O=F,Cl)	-0.68	-0.54	-0.48	-0.72	-0.42	-0.50	-0.48	-0.60	-0.57	-0.59	-0.62	-0.54
Total	99.58	101.31	101.33	99.90	100.89	101.49	100.70	100.38	99.78	100.32	100.54	100.85
T Si (apfu)	5.874	5.794	5.696	5.825	5.749	5.804	5.763	5.758	5.672	5.724	5.732	5.733
T Al	0.126	0.206	0.304	0.175	0.251	0.196	0.237	0.242	0.328	0.276	0.268	0.267
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.061	0.038	0.038	0.035	0.030	0.029	0.047	0.031	0.040	0.043	0.042	0.051
Y Al	0.762	1.161	1.182	1.117	1.131	1.073	1.142	1.146	1.154	1.134	1.097	1.126
Y Cr	0.004	0.004	0.000	0.000	0.005	0.004	0.000	0.004	0.003	0.005	0.000	0.003
Y Fe ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y Fe ²⁺	1.281	0.514	0.520	0.418	0.613	0.698	0.536	0.605	0.617	0.582	0.579	0.595
Y Mn	0.118	0.386	0.392	0.471	0.525	0.498	0.381	0.342	0.369	0.366	0.381	0.332
Y Zn	0.005	0.008	0.000	0.001	0.010	0.007	0.000	0.002	0.005	0.000	0.009	0.005
Y Mg	0.154	0.042	0.036	0.036	0.036	0.051	0.051	0.037	0.040	0.039	0.041	0.053
Y Li	0.614	0.848	0.832	0.922	0.650	0.640	0.843	0.832	0.772	0.831	0.851	0.835
X Ca	0.007	0.016	0.016	0.010	0.004	0.007	0.014	0.008	0.015	0.015	0.026	0.009
X Na	0.830	0.775	0.842	0.885	0.692	0.683	0.810	0.843	0.833	0.847	0.879	0.847
x K	0.008	0.005	0.005	0.004	0.005	0.005	0.007	0.003	0.000	0.005	0.007	0.005
X vac	0.155	0.204	0.138	0.101	0.299	0.306	0.170	0.146	0.151	0.133	0.088	0.138
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.844	0.641	0.576	0.879	0.509	0.610	0.574	0.722	0.690	0.720	0.753	0.657
W Cl	0.008	0.003	0.000	0.000	0.001	0.001	0.002	0.002	0.002	0.001	0.001	0.001
W OH	0.148	0.357	0.424	0.121	0.490	0.389	0.424	0.276	0.308	0.279	0.246	0.342
W O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Classif.	fluor-schorl	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site	GARPPOS-S01/S02						GARPPOS-S03				GARPPOS-S03	
Comments	tiny bottom tur rim	tiny bottom tur rim	black tur from elbaite area: core	black tur from elbaite area: core	black tur from elbaite area: rim	black tur from elbaite area: rim	tiny tur: core	tiny tur: core	tiny tur: rim	tiny tur: rim	medium tur: core	medium tur: core
Point	GP3-25	GP3-26	48t-1	48t-2	48t-3	48t-4	49t-1	49t-2	49t-3	49t-4	50t-1	50t-2
SiO ₂ (wt.%)	36.37	35.59	33.58	34.16	36.38	36.10	35.96	35.99	35.34	35.17	35.64	35.38
TiO ₂	0.22	0.18	0.23	0.29	0.21	0.37	0.57	0.52	0.55	0.55	0.47	0.58
B ₂ O ₃ *	10.81	10.78	10.34	10.38	10.73	10.74	10.65	10.63	10.50	10.44	10.53	10.52
Al ₂ O ₃	38.78	39.91	36.78	36.31	37.93	38.15	33.47	33.31	32.75	32.27	32.15	32.64
Cr ₂ O ₃	0.00	0.03	0.00	0.00	0.03	0.03	0.02	0.04	0.04	0.09	0.03	0.00
Bi ₂ O ₃												
Fe ₂ O ₃ *	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO*	1.57	0.86	10.21	10.08	2.35	2.34	4.92	5.08	7.70	7.52	7.75	7.23
FeO (tot)	1.57	0.86	10.21	10.08	2.35	2.34	4.92	5.08	7.70	7.52	7.75	7.23
MnO	4.14	4.04	2.11	2.04	3.84	3.59	0.00	0.00	0.07	0.05	0.10	0.00
ZnO	0.03	0.07	0.54	0.59	0.13	0.10	0.04	0.06	0.04	0.00	0.05	0.00
MgO	0.07	0.02	0.08	0.08	0.03	0.05	7.98	7.89	6.54	6.76	6.95	7.02
Li ₂ O*	1.53	1.49	0.31	0.43	1.49	1.53	0.00	0.00	0.00	0.00	0.00	0.00
CaO	0.06	0.07	0.04	0.06	0.04	0.06	0.91	0.87	0.92	0.92	1.10	1.00
Na ₂ O	2.78	2.65	1.69	1.83	2.77	2.92	2.00	1.92	1.78	1.86	1.91	1.82
K ₂ O	0.03	0.02	0.03	0.03	0.03	0.01	0.05	0.05	0.06	0.06	0.05	0.07
F	1.36	1.45	0.61	0.59	1.62	1.51	0.38	0.42	0.13	0.31	0.23	0.25
Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.01
H ₂ O*	3.09	3.03	3.28	3.30	2.94	2.99	3.23	3.24	3.44	3.33	3.39	3.38
-(O=F,Cl)	-0.57	-0.61	-0.26	-0.25	-0.68	-0.64	-0.16	-0.18	-0.06	-0.13	-0.10	-0.11
Total	100.25	99.58	99.57	99.93	99.82	99.86	100.03	99.83	99.80	99.21	100.24	99.79
T Si (apfu)	5.847	5.740	5.646	5.717	5.893	5.843	5.870	5.886	5.847	5.856	5.883	5.846
T Al	0.153	0.260	0.354	0.283	0.107	0.157	0.130	0.114	0.153	0.144	0.117	0.154
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.026	0.022	0.029	0.037	0.025	0.045	0.070	0.064	0.068	0.069	0.059	0.072
Y Al	1.193	1.325	0.935	0.879	1.133	1.121	0.309	0.306	0.234	0.188	0.138	0.201
Y Cr	0.000	0.004	0.000	0.000	0.004	0.004	0.003	0.005	0.006	0.012	0.004	0.000
Y Fe ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y Fe ²⁺	0.210	0.116	1.436	1.410	0.319	0.317	0.671	0.695	1.066	1.047	1.070	0.999
Y Mn	0.563	0.551	0.300	0.290	0.526	0.492	0.000	0.000	0.010	0.007	0.014	0.000
Y Zn	0.003	0.008	0.067	0.073	0.016	0.011	0.005	0.007	0.005	0.000	0.006	0.000
Y Mg	0.016	0.005	0.020	0.020	0.007	0.012	1.942	1.923	1.612	1.678	1.709	1.728
Y Li	0.987	0.969	0.212	0.291	0.969	0.998	0.000	0.000	0.000	0.000	0.000	0.000
X Ca	0.010	0.013	0.008	0.011	0.007	0.010	0.159	0.152	0.162	0.164	0.194	0.177
X Na	0.868	0.827	0.551	0.593	0.869	0.917	0.634	0.610	0.570	0.601	0.611	0.581
x K	0.006	0.004	0.005	0.007	0.006	0.002	0.011	0.011	0.012	0.014	0.011	0.015
X vac	0.116	0.156	0.436	0.389	0.119	0.071	0.196	0.227	0.256	0.221	0.184	0.226
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.689	0.741	0.323	0.310	0.828	0.773	0.195	0.219	0.069	0.163	0.119	0.132
W Cl	0.000	0.001	0.000	0.000	0.000	0.001	0.001	0.000	0.002	0.003	0.000	0.002
W OH	0.311	0.258	0.677	0.690	0.172	0.226	0.522	0.531	0.801	0.699	0.728	0.725
W O	0.000	0.000	0.000	0.000	0.000	0.000	0.283	0.250	0.129	0.135	0.153	0.141
Classif.	fluor-elbaite	fluor-elbaite	schorl	schorl	fluor-elbaite	fluor-elbaite	dravite	dravite	dravite	dravite	dravite	dravite

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site	GARPHOS-S03		GARPHOS-S03		GARPHOS-S03		GARTOUR-S01					
Comments	medium tur: rim	medium tur: rim	big tur (homogeneous)	big tur (homogeneous)	long xtl tur top	long xtl tur top	long xtl tur base core	long xtl tur base core	long xtl tur base rim	long xtl tur base rim	black tur core	black tur core
Point	50t-3	50t-4	51t-1	51t-2	52t-1	52t-2	53t-1	53t-2	53t-3	53t-4	54t-1	54t-2
SiO ₂ (wt.%)	34.52	34.26	35.26	35.15	35.58	35.60	34.88	35.16	33.81	33.84	34.63	34.37
TiO ₂	0.11	0.11	0.55	0.48	0.35	0.41	0.56	0.55	0.60	0.58	0.71	0.62
B ₂ O ₃ *	10.30	10.31	10.50	10.44	10.47	10.48	10.42	10.50	10.22	10.28	10.44	10.34
Al ₂ O ₃	32.59	32.82	33.06	32.88	33.22	33.06	32.94	33.16	33.27	33.31	34.98	34.65
Cr ₂ O ₃	0.00	0.03	0.00	0.00	0.00	0.03	0.00	0.02	0.00	0.00	0.03	0.03
Bi ₂ O ₃												
Fe ₂ O ₃ *	0.53	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO*	12.84	12.26	8.19	8.22	9.70	9.80	8.99	9.05	13.26	13.38	13.61	13.54
FeO (tot)	13.31	13.12	8.19	8.22	9.70	9.80	8.99	9.05	13.26	13.38	13.61	13.54
MnO	0.30	0.35	0.13	0.08	0.08	0.10	0.09	0.08	0.31	0.33	0.15	0.20
ZnO	0.06	0.03	0.03	0.00	0.00	0.02	0.02	0.02	0.08	0.00	0.08	0.00
MgO	2.99	3.13	6.03	5.99	4.82	4.85	5.52	5.61	2.21	2.51	0.83	0.86
Li ₂ O*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.18
CaO	0.33	0.31	0.73	0.74	0.32	0.31	0.52	0.56	0.30	0.25	0.17	0.17
Na ₂ O	1.97	2.02	1.96	1.85	1.84	1.81	2.02	2.16	1.94	2.10	1.58	1.43
K ₂ O	0.05	0.03	0.05	0.05	0.06	0.02	0.03	0.05	0.06	0.03	0.05	0.03
F	0.28	0.25	0.12	0.17	0.20	0.31	0.13	0.27	0.08	0.11	0.32	0.23
Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.01
H ₂ O*	3.42	3.44	3.42	3.39	3.41	3.40	3.45	3.37	3.40	3.49	3.45	3.45
-(O=F,Cl)	-0.12	-0.10	-0.05	-0.07	-0.08	-0.13	-0.06	-0.12	-0.04	-0.05	-0.14	-0.10
Total	100.18	100.19	99.99	99.36	99.97	100.06	99.52	100.44	99.49	100.16	101.12	100.01
T Si (apfu)	5.825	5.774	5.837	5.850	5.906	5.906	5.815	5.817	5.752	5.720	5.764	5.779
T Al	0.175	0.226	0.163	0.150	0.094	0.094	0.185	0.183	0.248	0.280	0.236	0.221
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.014	0.013	0.069	0.060	0.044	0.051	0.070	0.068	0.076	0.074	0.088	0.079
Y Al	0.304	0.294	0.287	0.300	0.405	0.370	0.289	0.282	0.425	0.355	0.625	0.647
Y Cr	0.000	0.004	0.000	0.000	0.000	0.004	0.000	0.002	0.000	0.000	0.004	0.004
Y Fe ³⁺	0.067	0.121	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y Fe ²⁺	1.811	1.728	1.134	1.144	1.347	1.359	1.253	1.252	1.886	1.891	1.894	1.904
Y Mn	0.043	0.049	0.019	0.012	0.011	0.014	0.013	0.011	0.044	0.047	0.021	0.028
Y Zn	0.008	0.004	0.003	0.000	0.000	0.002	0.002	0.002	0.009	0.000	0.010	0.000
Y Mg	0.753	0.787	1.488	1.485	1.193	1.199	1.372	1.383	0.559	0.632	0.207	0.216
Y Li	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.151	0.122
X Ca	0.060	0.056	0.129	0.133	0.057	0.055	0.093	0.100	0.055	0.046	0.030	0.031
X Na	0.645	0.661	0.630	0.596	0.593	0.582	0.654	0.694	0.640	0.688	0.511	0.465
x K	0.012	0.007	0.010	0.010	0.013	0.004	0.007	0.011	0.014	0.006	0.010	0.007
X vac	0.283	0.276	0.231	0.261	0.337	0.359	0.246	0.195	0.291	0.260	0.449	0.497
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.148	0.133	0.065	0.091	0.106	0.161	0.070	0.141	0.045	0.058	0.171	0.123
W Cl	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.003	0.002	0.004
W OH	0.851	0.867	0.774	0.768	0.777	0.761	0.838	0.715	0.862	0.930	0.828	0.873
W O	0.000	0.000	0.161	0.141	0.117	0.079	0.092	0.142	0.094	0.009	0.000	0.000
Classif.	schorl	schorl	dravite	dravite	schorl	schorl	dravite	dravite	schorl	schorl	schorl	foitite

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site	GRANITE-S01						GRANITE - S01					
Comments	black tur intermediate	black tur intermediate	black tur inner rim	black tur inner rim	black tur outer rim	black tur outer rim	border tur	border tur	core tur: core	core tur: core	core tur: intermediate	core tur: intermediate
Point	54t-3	54t-4	54t-5	54t-6	54t-7	54t-8	10t-1	10t-2	11t-1	11t-2	11t-3	11t-4
SiO ₂ (wt.%)	34.24	34.51	35.16	35.33	36.86	36.52	34.85	35.15	34.79	34.23	34.66	34.55
TiO ₂	0.53	0.57	0.02	0.05	0.08	0.09	1.02	0.81	0.76	0.73	1.01	0.89
B ₂ O ₃ *	10.33	10.39	10.51	10.61	10.74	10.71	10.45	10.46	10.47	10.29	10.42	10.39
Al ₂ O ₃	34.82	34.72	34.95	35.18	33.73	33.99	31.81	31.57	33.05	32.64	32.43	32.46
Cr ₂ O ₃	0.00	0.00	0.01	0.02	0.01	0.01	0.00	0.00	0.04	0.00	0.01	0.00
Bi ₂ O ₃												
Fe ₂ O ₃ *	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO*	13.77	13.90	9.64	9.76	6.41	6.89	8.52	8.38	7.67	8.56	8.20	8.85
FeO (tot)	13.77	13.90	9.65	9.76	6.41	6.89	8.52	8.38	7.67	8.56	8.20	8.85
MnO	0.17	0.21	0.19	0.23	0.11	0.10	0.08	0.06	0.09	0.04	0.06	0.07
ZnO	0.05	0.04	0.04	0.10	0.07	0.00	0.04	0.00	0.05	0.00	0.02	0.01
MgO	0.76	0.78	3.77	4.00	6.57	6.23	6.62	6.85	6.37	5.60	6.25	5.86
Li ₂ O*	0.15	0.20	0.12	0.08	0.18	0.16	0.00	0.00	0.00	0.00	0.00	0.00
CaO	0.12	0.13	0.17	0.19	0.34	0.26	1.26	1.31	1.01	1.05	1.11	1.10
Na ₂ O	1.49	1.66	1.81	1.88	1.98	2.00	1.80	1.79	1.72	1.76	1.80	1.78
K ₂ O	0.03	0.03	0.01	0.03	0.02	0.02	0.05	0.05	0.02	0.06	0.05	0.05
F	0.26	0.24	0.19	0.34	0.44	0.39	0.16	0.12	0.21	0.08	0.24	0.25
Cl	0.00	0.01	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01
H ₂ O*	3.44	3.47	3.54	3.50	3.50	3.51	3.42	3.44	3.40	3.32	3.31	3.32
-(O=F,Cl)	-0.11	-0.10	-0.08	-0.15	-0.18	-0.16	-0.07	-0.05	-0.09	-0.03	-0.10	-0.11
Total	100.04	100.76	100.07	101.16	100.87	100.70	100.02	99.94	99.57	98.32	99.49	99.49
T Si (apfu)	5.763	5.775	5.811	5.788	5.962	5.927	5.796	5.842	5.773	5.783	5.783	5.779
T Al	0.237	0.225	0.189	0.212	0.038	0.073	0.204	0.158	0.227	0.217	0.217	0.221
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.067	0.072	0.002	0.006	0.010	0.011	0.128	0.101	0.095	0.093	0.127	0.112
Y Al	0.671	0.622	0.620	0.580	0.392	0.429	0.029	0.027	0.239	0.282	0.160	0.178
Y Cr	0.000	0.000	0.001	0.003	0.002	0.002	0.000	0.000	0.006	0.000	0.001	0.000
Y Fe ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y Fe ²⁺	1.938	1.945	1.333	1.337	0.867	0.935	1.185	1.165	1.065	1.209	1.144	1.237
Y Mn	0.025	0.030	0.027	0.032	0.015	0.013	0.011	0.009	0.013	0.006	0.009	0.010
Y Zn	0.007	0.005	0.005	0.012	0.009	0.000	0.005	0.000	0.007	0.000	0.003	0.002
Y Mg	0.191	0.193	0.930	0.977	1.585	1.507	1.642	1.698	1.576	1.410	1.555	1.461
Y Li	0.101	0.132	0.082	0.054	0.120	0.102	0.000	0.000	0.000	0.000	0.000	0.000
X Ca	0.021	0.023	0.031	0.034	0.059	0.045	0.224	0.234	0.180	0.190	0.198	0.198
X Na	0.485	0.538	0.581	0.597	0.621	0.629	0.581	0.576	0.552	0.575	0.581	0.577
x K	0.007	0.007	0.003	0.006	0.004	0.004	0.010	0.010	0.004	0.014	0.010	0.011
X vac	0.487	0.432	0.385	0.363	0.316	0.322	0.185	0.180	0.264	0.221	0.211	0.214
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.137	0.127	0.101	0.177	0.225	0.200	0.085	0.063	0.112	0.040	0.128	0.134
W Cl	0.000	0.003	0.000	0.002	0.000	0.000	0.002	0.000	0.000	0.000	0.001	0.002
W OH	0.863	0.870	0.899	0.821	0.775	0.800	0.792	0.813	0.764	0.740	0.684	0.699
W O	0.000	0.000	0.000	0.000	0.000	0.000	0.120	0.125	0.124	0.220	0.187	0.164
Classif.	schorl	schorl	schorl	schorl	dravite	dravite	dravite	dravite	dravite	dravite	dravite	dravite

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site	GRANITE-S05						GRANITE S05-1					
Comments	core tur. rim	core tur. rim	black tur core	black tur core	black tur rim	black tur rim	skinny tur top	skinny tur top	skinny tur bottom dark in BSE	skinny tur bottom dark in BSE	skinny tur bottom light in BSE	skinny tur bottom light in BSE
Point	11t-5	11t-6	17t-1	17t-2	17t-3	17t-4	GN5-1	GN5-2	GN5-3	GN5-4	GN5-5	GN5-6
SiO ₂ (wt.%)	32.95	33.71	34.89	34.83	34.77	34.28	36.22	36.09	35.89	36.38	35.37	35.84
TiO ₂	1.13	1.01	0.48	0.48	0.44	0.53	1.95	0.52	0.33	0.25	1.58	1.60
B ₂ O ₃ *	10.16	10.22	10.43	10.48	10.39	10.31	10.49	10.59	10.56	10.58	10.38	10.41
Al ₂ O ₃	32.14	31.46	33.21	33.34	31.89	32.50	30.38	32.93	33.15	33.55	30.06	29.62
Cr ₂ O ₃	0.06	0.03	0.03	0.00	0.03	0.02	0.00	0.00	0.00	0.01	0.00	0.00
Bi ₂ O ₃												
Fe ₂ O ₃ *	0.00	0.30	0.00	0.00	0.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO*	11.08	11.21	8.68	8.90	9.54	10.01	7.23	7.01	7.18	6.21	8.23	8.37
FeO (tot)	11.08	11.48	8.68	8.90	10.35	10.01	7.23	7.01	7.18	6.21	8.23	8.37
MnO	0.15	0.13	0.08	0.07	0.11	0.08	0.10	0.12	0.09	0.14	0.05	0.09
ZnO	0.01	0.04	0.00	0.00	0.05	0.08	0.00	0.00	0.00	0.01	0.06	0.00
MgO	4.40	4.63	5.56	5.67	5.52	5.02	7.34	6.78	6.58	6.60	7.14	7.28
Li 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
CaO	1.19	1.04	0.76	0.79	0.62	0.64	0.35	0.33	0.34	0.26	0.53	0.45
Na ₂ O	1.60	1.64	1.87	1.89	1.94	1.98	2.33	2.32	2.28	2.12	2.26	2.32
K ₂ O	0.04	0.05	0.08	0.06	0.05	0.04	0.02	0.04	0.05	0.03	0.06	0.03
F	0.14	0.12	0.21	0.15	0.34	0.20	0.36	0.23	0.26	0.34	0.45	0.34
Cl	0.00	0.00	0.01	0.00	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.01
H ₂ O*	3.41	3.47	3.35	3.46	3.42	3.42	3.19	3.34	3.34	3.22	3.28	3.33
-(O=F,Cl)	-0.06	-0.05	-0.09	-0.07	-0.15	-0.09	-0.15	-0.10	-0.11	-0.14	-0.19	-0.14
Total	98.41	99.01	99.56	100.03	99.87	99.04	99.82	100.21	99.95	99.55	99.26	99.54
T Si (apfu)	5.636	5.732	5.813	5.777	5.813	5.779	5.998	5.925	5.909	5.979	5.920	5.982
T Al	0.364	0.268	0.187	0.223	0.187	0.221	0.002	0.075	0.091	0.021	0.080	0.018
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	5.929	6.000	6.000	6.000	5.850	5.808
Y Ti	0.145	0.129	0.060	0.059	0.055	0.067	0.242	0.064	0.041	0.030	0.199	0.201
Y Al	0.116	0.036	0.334	0.295	0.098	0.236	0.000	0.297	0.343	0.477	0.000	0.000
Y Cr	0.009	0.005	0.004	0.000	0.004	0.003	0.000	0.000	0.001	0.002	0.000	0.000
Y Fe ³⁺	0.000	0.038	0.000	0.000	0.112	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y Fe ²⁺	1.586	1.594	1.209	1.234	1.334	1.411	1.002	0.963	0.989	0.853	1.152	1.168
Y Mn	0.022	0.019	0.012	0.010	0.015	0.011	0.015	0.017	0.012	0.019	0.007	0.013
Y Zn	0.001	0.004	0.000	0.000	0.006	0.010	0.000	0.000	0.001	0.001	0.008	0.000
Y Mg	1.121	1.174	1.381	1.402	1.375	1.261	1.812	1.659	1.614	1.617	1.783	1.810
Y Li	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
X Ca	0.219	0.190	0.135	0.140	0.112	0.116	0.062	0.058	0.061	0.045	0.095	0.081
X Na	0.531	0.541	0.605	0.607	0.627	0.648	0.749	0.740	0.729	0.675	0.733	0.750
x K	0.008	0.010	0.017	0.012	0.011	0.008	0.004	0.009	0.009	0.006	0.012	0.007
X vac	0.242	0.259	0.243	0.242	0.250	0.228	0.185	0.193	0.200	0.273	0.160	0.163
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.074	0.067	0.108	0.081	0.182	0.108	0.189	0.118	0.136	0.174	0.237	0.178
W Cl	0.001	0.000	0.002	0.000	0.002	0.003	0.000	0.003	0.001	0.000	0.001	0.002
W OH	0.896	0.933	0.728	0.829	0.816	0.850	0.521	0.663	0.668	0.535	0.657	0.711
W O	0.029	0.000	0.162	0.089	0.000	0.040	0.289	0.216	0.195	0.291	0.104	0.109
Classif.	schorl	schorl	dravite	dravite	dravite	schorl	dravite	dravite	dravite	dravite	dravite	dravite

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site	GRANITE-S03				GRANITE S03-1							
Comments	fractured tur light in BSE	fractured tur light in BSE	black homogenous tur	black homogenous tur	oscillatory zoned tur: light BSE rim	oscillatory zoned tur: dark BSE	oscillatory zoned tur: light BSE	oscillatory zoned tur: dark BSE	oscillatory zoned tur: medium BSE	oscillatory zoned tur: dark BSE	oscillatory zoned tur: light BSE	oscillatory zoned tur: medium BSE
Point	GN5-9	GN5-10	12t-1	12t-2	GN3-1	GN3-2	GN3-3	GN3-4	GN3-5	GN3-6	GN3-7	GN3-8
SiO ₂ (wt.%)	35.00	35.39	35.05	35.15	34.52	36.10	35.58	36.08	35.92	36.48	35.50	36.83
TiO ₂	0.42	0.33	0.45	0.36	0.89	0.65	0.67	0.66	0.57	0.62	0.67	0.52
B ₂ O ₃ *	10.40	10.47	10.42	10.42	10.32	10.58	10.51	10.60	10.55	10.66	10.46	10.68
Al ₂ O ₃	33.41	33.47	32.85	33.03	33.06	33.32	32.97	32.67	32.85	33.00	32.23	32.49
Cr ₂ O ₃	0.00	0.02	0.00	0.02	0.01	0.02	0.00	0.00	0.05	0.02	0.00	0.00
Bi ₂ O ₃												
Fe ₂ O ₃ *	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO*	8.19	8.04	8.26	8.66	9.93	7.75	8.90	7.50	8.05	8.12	9.44	7.63
FeO (tot)	8.19	8.04	8.26	8.66	9.93	7.75	8.90	7.50	8.05	8.12	9.44	7.63
MnO	0.08	0.07	0.05	0.03	0.11	0.11	0.11	0.06	0.08	0.12	0.17	0.12
ZnO	0.07	0.00	0.00	0.01	0.00	0.10	0.00	0.00	0.04	0.09	0.00	0.00
MgO	5.45	5.68	5.95	5.57	4.38	5.87	5.53	6.78	6.12	6.18	5.52	6.82
Li 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
CaO	0.73	0.63	0.89	0.81	0.68	0.71	0.73	0.84	0.72	0.67	0.67	0.82
Na ₂ O	1.84	1.85	1.93	1.88	1.89	1.90	1.88	2.08	1.98	2.01	2.03	2.27
K ₂ O	0.06	0.06	0.06	0.06	0.05	0.02	0.05	0.05	0.04	0.04	0.06	0.07
F	0.26	0.27	0.50	0.17	0.05	0.00	0.25	0.27	0.25	0.12	0.15	0.26
Cl	0.00	0.01	0.00	0.01	0.00	0.00	0.01	0.01	0.00	0.01	0.00	0.01
H ₂ O*	3.24	3.28	3.16	3.32	3.29	3.34	3.30	3.28	3.29	3.38	3.37	3.22
-(O=F,Cl)	-0.11	-0.12	-0.21	-0.07	-0.02	0.00	-0.11	-0.12	-0.11	-0.05	-0.06	-0.11
Total	99.04	99.47	99.36	99.42	99.14	100.46	100.38	100.76	100.40	101.47	100.19	101.62
T Si (apfu)	5.848	5.875	5.848	5.862	5.812	5.933	5.882	5.914	5.917	5.946	5.900	5.995
T Al	0.152	0.125	0.152	0.138	0.188	0.067	0.118	0.086	0.083	0.054	0.100	0.005
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.052	0.042	0.057	0.045	0.112	0.081	0.083	0.081	0.070	0.076	0.084	0.063
Y Al	0.426	0.425	0.305	0.354	0.374	0.386	0.307	0.225	0.295	0.284	0.213	0.227
Y Cr	0.000	0.003	0.000	0.003	0.002	0.003	0.000	0.000	0.006	0.002	0.000	0.000
Y Fe ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y Fe ²⁺	1.144	1.116	1.152	1.208	1.398	1.065	1.231	1.028	1.109	1.107	1.312	1.039
Y Mn	0.011	0.010	0.007	0.005	0.015	0.015	0.016	0.008	0.011	0.017	0.024	0.017
Y Zn	0.009	0.000	0.000	0.001	0.000	0.012	0.000	0.000	0.005	0.011	0.000	0.000
Y Mg	1.358	1.405	1.479	1.385	1.099	1.438	1.363	1.657	1.503	1.503	1.367	1.654
Y Li	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
X Ca	0.130	0.113	0.159	0.144	0.122	0.125	0.130	0.147	0.128	0.118	0.119	0.142
X Na	0.595	0.595	0.624	0.607	0.616	0.605	0.601	0.660	0.633	0.636	0.654	0.717
x K	0.012	0.013	0.013	0.012	0.010	0.003	0.011	0.011	0.008	0.007	0.012	0.014
X vac	0.262	0.279	0.203	0.237	0.252	0.267	0.258	0.182	0.232	0.239	0.214	0.127
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.139	0.142	0.262	0.089	0.025	0.000	0.129	0.141	0.131	0.060	0.076	0.134
W Cl	0.000	0.003	0.001	0.003	0.000	0.000	0.004	0.002	0.000	0.002	0.000	0.002
W OH	0.615	0.635	0.515	0.691	0.693	0.658	0.640	0.591	0.616	0.677	0.738	0.501
W O	0.247	0.220	0.223	0.217	0.283	0.342	0.227	0.266	0.254	0.262	0.186	0.364
Classif.	dravite	dravite	dravite	dravite	schorl	dravite	dravite	dravite	dravite	dravite	dravite	dravite

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site	GRANITE S04-1										GRANITE - S04	
Comments	oscillatory zoned tur: dark BSE	oscillatory zoned tur: medium BSE core	oscillatory zoned tur: light BSE core	oscillatory zoned tur: dark BSE core	qz-tur intergrowth left	qz-tur intergrowth left	qz-tur intergrowth center	qz-tur intergrowth center	qz-tur intergrowth right	qz-tur intergrowth right	tur from intergrowth (homogeneous)	tur from intergrowth (homogeneous)
Point	GN3-9	GN3-10	GN3-11	GN3-12	GN4-1	GN4-2	GN4-3	GN4-4	GN4-5	GN4-6	13t-1	13t-2
SiO ₂ (wt.%)	36.40	36.37	35.73	37.63	35.34	35.65	35.58	35.29	35.22	35.58	35.85	35.88
TiO ₂	0.31	1.23	0.91	0.34	0.43	0.59	0.34	0.33	0.50	0.48	0.48	0.61
B ₂ O ₃ *	10.64	10.55	10.48	10.90	10.46	10.56	10.53	10.47	10.42	10.49	10.56	10.51
Al ₂ O ₃	33.36	31.00	31.24	33.32	33.38	33.38	33.14	33.03	33.25	33.92	33.42	33.15
Cr ₂ O ₃	0.01	0.03	0.00	0.02	0.02	0.01	0.00	0.06	0.00	0.04	0.01	0.01
Bi ₂ O ₃												
Fe ₂ O ₃ *	0.00	0.00	0.00	3.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO*	7.46	7.69	8.37	3.62	7.82	7.93	7.99	7.81	7.92	7.62	8.29	8.18
FeO (tot)	7.46	7.69	8.37	6.61	7.82	7.93	7.99	7.81	7.92	7.62	8.29	8.18
MnO	0.16	0.21	0.13	0.22	0.03	0.10	0.09	0.03	0.04	0.09	0.07	0.08
ZnO	0.01	0.05	0.03	0.02	0.00	0.02	0.03	0.01	0.00	0.00	0.06	0.00
MgO	6.39	7.10	6.75	6.58	5.80	6.01	6.18	6.22	5.69	5.48	5.68	5.60
Li 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
CaO	0.55	1.21	1.03	0.48	0.69	0.75	0.89	0.88	0.67	0.62	0.57	0.61
Na ₂ O	1.75	1.80	1.79	1.69	1.84	1.87	1.84	1.70	1.88	1.92	2.08	1.93
K ₂ O	0.04	0.04	0.06	0.05	0.06	0.03	0.04	0.05	0.05	0.04	0.07	0.03
F	0.10	0.23	0.12	0.01	0.20	0.31	0.36	0.29	0.24	0.37	0.25	0.08
Cl	0.02	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00
H ₂ O*	3.50	3.24	3.42	3.76	3.28	3.29	3.29	3.35	3.24	3.10	3.26	3.29
-(O=F,Cl)	-0.05	-0.10	-0.05	0.00	-0.09	-0.13	-0.15	-0.12	-0.10	-0.16	-0.11	-0.04
Total	100.64	100.66	100.01	101.96	99.27	100.34	100.14	99.41	99.01	99.61	100.54	99.93
T Si (apfu)	5.944	5.990	5.927	6.000	5.874	5.868	5.873	5.858	5.875	5.892	5.902	5.935
T Al	0.056	0.010	0.073	0.000	0.126	0.132	0.127	0.142	0.125	0.108	0.098	0.065
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.038	0.152	0.113	0.041	0.054	0.073	0.042	0.042	0.063	0.060	0.059	0.076
Y Al	0.363	0.007	0.036	0.260	0.415	0.344	0.320	0.320	0.412	0.514	0.387	0.399
Y Cr	0.001	0.004	0.000	0.003	0.003	0.001	0.000	0.008	0.000	0.005	0.001	0.001
Y Fe ³⁺	0.000	0.000	0.000	0.399	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y Fe ²⁺	1.019	1.059	1.161	0.482	1.087	1.092	1.102	1.085	1.104	1.055	1.142	1.132
Y Mn	0.022	0.029	0.018	0.030	0.005	0.014	0.013	0.005	0.006	0.012	0.009	0.011
Y Zn	0.001	0.007	0.003	0.002	0.000	0.002	0.003	0.002	0.000	0.000	0.007	0.000
Y Mg	1.556	1.742	1.669	1.563	1.437	1.475	1.520	1.539	1.416	1.353	1.394	1.381
Y Li	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
X Ca	0.096	0.213	0.184	0.083	0.122	0.132	0.157	0.156	0.120	0.110	0.101	0.107
X Na	0.553	0.576	0.577	0.522	0.594	0.596	0.588	0.546	0.609	0.618	0.664	0.618
x K	0.009	0.008	0.013	0.010	0.012	0.006	0.009	0.011	0.010	0.009	0.014	0.007
X vac	0.343	0.203	0.226	0.385	0.271	0.266	0.245	0.286	0.261	0.263	0.221	0.268
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.053	0.120	0.064	0.005	0.107	0.159	0.189	0.154	0.127	0.194	0.129	0.044
W Cl	0.004	0.001	0.001	0.000	0.000	0.001	0.002	0.000	0.000	0.001	0.002	0.001
W OH	0.808	0.563	0.788	0.995	0.642	0.617	0.620	0.706	0.602	0.428	0.579	0.628
W O	0.135	0.315	0.147	0.000	0.251	0.223	0.189	0.139	0.271	0.378	0.289	0.327
Classif.	dravite	dravite	dravite	dravite	dravite	dravite	dravite	dravite	dravite	dravite	dravite	dravite

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site	GRANITE - S04 (coarse turn)								GRANITE - S06			
Comments	area 2 longer tur: core	area 2 longer tur: core	area 2 longer tur: rim	area 2 longer tur: rim	area 3 longer tur: core	area 3 longer tur: core	area 3 longer tur: rim	area 3 longer tur: rim	oscillatory tur: (inner most) dark BSE	oscillatory tur: (inner most) dark BSE	oscillatory tur: light BSE	oscillatory tur: light BSE
Point	14t-1	14t-2	14t-3	14t-4	14t-5	14t-6	14t-7	14t-8	18t-1	18t-2	18t-3	18t-4
SiO ₂ (wt.%)	34.77	34.58	34.48	34.00	34.90	34.03	34.05	34.60	33.62	33.42	33.44	33.07
TiO ₂	0.44	0.45	0.56	0.60	0.53	0.49	0.38	0.54	0.64	0.65	0.72	0.80
B ₂ O ₃ *	10.52	10.45	10.42	10.32	10.55	10.42	10.43	10.45	10.30	10.24	10.27	10.27
Al ₂ O ₃	33.98	33.89	33.80	33.57	34.04	33.95	33.63	33.70	33.43	33.52	33.41	33.85
Cr ₂ O ₃	0.00	0.02	0.03	0.03	0.02	0.00	0.00	0.00	0.01	0.00	0.04	0.00
Bi ₂ O ₃												
Fe ₂ O ₃ *	0.00	0.00	0.00	0.00	0.00	0.52	1.15	0.00	0.09	0.00	0.00	0.00
FeO*	8.18	7.92	9.68	9.29	7.86	7.49	7.75	9.06	8.77	8.69	8.98	9.25
FeO (tot)	8.18	7.92	9.68	9.29	7.86	7.96	8.79	9.06	8.85	8.69	8.98	9.25
MnO	0.06	0.05	0.16	0.09	0.08	0.08	0.10	0.10	0.13	0.07	0.12	0.04
ZnO	0.02	0.03	0.00	0.04	0.00	0.07	0.03	0.02	0.05	0.00	0.04	0.01
MgO	5.86	5.80	4.66	4.78	6.01	5.89	5.75	5.24	5.25	5.10	5.11	4.87
Li 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
CaO	0.68	0.69	0.38	0.47	0.74	0.69	0.52	0.58	0.65	0.54	0.67	0.68
Na ₂ O	1.89	1.80	1.82	1.87	1.84	1.66	1.89	1.88	1.78	1.80	1.82	1.95
K ₂ O	0.05	0.05	0.02	0.04	0.05	0.05	0.04	0.06	0.05	0.05	0.04	0.04
F	0.22	0.28	0.31	0.36	0.22	0.28	0.35	0.20	0.29	0.20	0.24	0.31
Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
H ₂ O*	3.46	3.39	3.43	3.33	3.44	3.47	3.43	3.45	3.41	3.42	3.41	3.35
-(O=F,Cl)	-0.09	-0.12	-0.13	-0.15	-0.09	-0.12	-0.15	-0.08	-0.12	-0.08	-0.10	-0.13
Total	100.03	99.28	99.62	98.63	100.18	98.97	99.35	99.81	98.36	97.61	98.22	98.35
T Si (apfu)	5.745	5.750	5.751	5.728	5.751	5.674	5.675	5.753	5.674	5.674	5.658	5.599
T Al	0.255	0.250	0.249	0.272	0.249	0.326	0.325	0.247	0.326	0.326	0.342	0.401
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.054	0.056	0.070	0.075	0.065	0.061	0.047	0.068	0.081	0.083	0.091	0.101
Y Al	0.362	0.392	0.394	0.394	0.361	0.346	0.281	0.356	0.322	0.381	0.322	0.354
Y Cr	0.000	0.002	0.005	0.005	0.003	0.000	0.000	0.000	0.002	0.000	0.005	0.000
Y Fe ³⁺	0.000	0.000	0.000	0.000	0.000	0.065	0.144	0.000	0.011	0.000	0.000	0.000
Y Fe ²⁺	1.131	1.101	1.350	1.308	1.084	1.045	1.081	1.260	1.238	1.234	1.271	1.310
Y Mn	0.009	0.007	0.022	0.013	0.011	0.011	0.015	0.014	0.019	0.010	0.016	0.005
Y Zn	0.002	0.003	0.000	0.005	0.000	0.009	0.004	0.003	0.007	0.000	0.005	0.002
Y Mg	1.443	1.438	1.159	1.200	1.476	1.463	1.429	1.299	1.320	1.291	1.289	1.228
Y Li	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
X Ca	0.120	0.123	0.069	0.084	0.131	0.123	0.094	0.103	0.118	0.099	0.121	0.123
X Na	0.605	0.579	0.587	0.612	0.589	0.537	0.610	0.606	0.582	0.594	0.598	0.641
x K	0.011	0.011	0.004	0.008	0.011	0.010	0.008	0.013	0.012	0.011	0.009	0.008
X vac	0.264	0.287	0.341	0.295	0.268	0.330	0.288	0.278	0.289	0.297	0.271	0.227
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.113	0.146	0.163	0.193	0.114	0.145	0.183	0.104	0.156	0.108	0.129	0.168
W Cl	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000
W OH	0.815	0.762	0.819	0.740	0.778	0.855	0.817	0.826	0.844	0.869	0.850	0.780
W O	0.072	0.093	0.018	0.067	0.108	0.000	0.000	0.070	0.000	0.023	0.018	0.052
Classif.	dravite	dravite	schorl	schorl	dravite	dravite	dravite	dravite	dravite	dravite	dravite	schorl

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site												
Comments	oscillatory tur: medium gray BSE	oscillatory tur: medium gray BSE	oscillatory tur: dark BSE	oscillatory tur: dark BSE	oscillatory tur: light BSE	oscillatory tur: light BSE	oscillatory tur: medium gray BSE	oscillatory tur: medium gray BSE	oscillatory tur: (middle) light BSE	oscillatory tur: (middle) light BSE	oscillatory tur: dark BSE	oscillatory tur: dark BSE
Point	18t-5	18t-6	18t-7	18t-8	18t-9	18t-10	18t-11	18t-12	18t-13	18t-14	18t-15	18t-16
SiO ₂ (wt.%)	33.49	32.31	33.26	33.55	32.79	33.05	33.11	33.37	32.76	32.52	32.59	32.67
TiO ₂	0.63	0.61	0.66	0.69	0.61	0.75	0.56	0.69	0.69	0.73	0.59	0.64
B ₂ O ₃ *	10.29	10.07	10.24	10.26	10.15	10.15	10.23	10.30	10.19	10.12	10.17	10.20
Al ₂ O ₃	33.90	33.54	33.57	33.39	34.17	33.78	33.81	33.92	34.20	34.37	34.09	34.09
Cr ₂ O ₃	0.04	0.02	0.02	0.00	0.03	0.02	0.01	0.05	0.00	0.05	0.01	0.03
Bi ₂ O ₃												
Fe ₂ O ₃ *	0.26	0.36	0.00	0.23	0.00	0.00	0.35	0.61	0.43	0.00	0.44	0.64
FeO*	9.56	10.32	8.69	8.67	12.16	12.14	10.05	9.83	10.86	11.92	10.26	10.14
FeO (tot)	9.80	10.64	8.69	8.87	12.16	12.14	10.36	10.38	11.24	11.92	10.65	10.71
MnO	0.13	0.15	0.11	0.11	0.13	0.11	0.11	0.11	0.15	0.17	0.12	0.09
ZnO	0.02	0.05	0.03	0.00	0.00	0.00	0.04	0.04	0.00	0.05	0.10	0.04
MgO	4.38	3.74	5.11	5.11	2.55	2.62	4.10	4.12	3.22	2.41	3.66	3.77
Li 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
CaO	0.51	0.63	0.57	0.56	0.42	0.46	0.55	0.49	0.53	0.44	0.48	0.46
Na ₂ O	1.66	1.73	1.80	1.67	1.68	1.59	1.76	1.65	1.54	1.59	1.80	1.79
K ₂ O	0.04	0.06	0.05	0.05	0.05	0.04	0.06	0.04	0.03	0.04	0.04	0.06
F	0.38	0.03	0.22	0.26	0.19	0.21	0.22	0.33	0.25	0.16	0.08	0.28
Cl	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.00
H ₂ O*	3.37	3.46	3.43	3.42	3.41	3.37	3.42	3.40	3.39	3.40	3.47	3.39
-(O=F,Cl)	-0.16	-0.01	-0.09	-0.11	-0.08	-0.09	-0.09	-0.14	-0.11	-0.07	-0.03	-0.12
Total	98.50	97.08	97.66	97.85	98.25	98.22	98.28	98.81	98.13	97.91	97.85	98.16
T Si (apfu)	5.658	5.574	5.649	5.684	5.613	5.659	5.625	5.633	5.590	5.584	5.571	5.566
T Al	0.342	0.426	0.351	0.316	0.387	0.341	0.375	0.367	0.410	0.416	0.429	0.434
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.080	0.079	0.085	0.087	0.078	0.097	0.071	0.088	0.088	0.094	0.076	0.082
Y Al	0.407	0.393	0.368	0.350	0.508	0.476	0.396	0.382	0.468	0.539	0.438	0.411
Y Cr	0.005	0.003	0.002	0.000	0.004	0.003	0.001	0.006	0.000	0.007	0.001	0.004
Y Fe ³⁺	0.033	0.046	0.000	0.029	0.000	0.000	0.044	0.078	0.055	0.000	0.057	0.082
Y Fe ²⁺	1.351	1.489	1.234	1.228	1.741	1.739	1.428	1.388	1.549	1.711	1.466	1.445
Y Mn	0.019	0.022	0.016	0.016	0.018	0.016	0.016	0.015	0.022	0.025	0.017	0.013
Y Zn	0.002	0.007	0.003	0.000	0.000	0.000	0.005	0.005	0.000	0.006	0.012	0.005
Y Mg	1.103	0.961	1.293	1.290	0.650	0.669	1.038	1.038	0.818	0.618	0.933	0.958
Y Li	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
X Ca	0.093	0.117	0.104	0.102	0.077	0.085	0.100	0.089	0.097	0.081	0.088	0.084
X Na	0.542	0.578	0.592	0.550	0.557	0.528	0.578	0.538	0.511	0.529	0.598	0.592
x K	0.008	0.013	0.012	0.010	0.011	0.008	0.013	0.009	0.006	0.009	0.008	0.013
X vac	0.357	0.291	0.291	0.339	0.354	0.379	0.309	0.364	0.386	0.381	0.307	0.311
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.201	0.017	0.116	0.137	0.102	0.113	0.120	0.174	0.136	0.089	0.041	0.149
W Cl	0.003	0.002	0.000	0.000	0.002	0.002	0.000	0.000	0.002	0.000	0.000	0.000
W OH	0.796	0.981	0.884	0.862	0.890	0.847	0.880	0.826	0.861	0.892	0.959	0.850
W O	0.000	0.000	0.001	0.000	0.005	0.038	0.000	0.000	0.000	0.019	0.000	0.000
Classif.	schorl	schorl	dravite	dravite	schorl	schorl	schorl	schorl	schorl	schorl	schorl	schorl

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site												GRANITE - S07 (baby pe
Comments	oscillatory tur: light BSE	oscillatory tur: light BSE	oscillatory tur: dark BSE	oscillatory tur: dark BSE	oscillatory tur: light BSE	oscillatory tur: light BSE	oscillatory tur: dark BSE	oscillatory tur: dark BSE	oscillatory tur: (rim) medium gray BSE	oscillatory tur: (rim) medium gray BSE	"baby peg" core tur: core	"baby peg" core tur: core
Point	18t-17	18t-18	18t-19	18t-20	18t-21	18t-22	18t-23	18t-24	18t-25	18t-26	15t-1	15t-2
SiO ₂ (wt.%)	32.70	32.54	32.69	33.30	32.84	32.59	32.98	32.88	31.67	31.91	33.89	33.53
TiO ₂	0.66	0.56	0.63	0.69	0.71	0.59	0.66	0.71	0.94	1.05	0.61	0.64
B ₂ O ₃ *	10.21	10.08	10.16	10.31	10.16	10.11	10.34	10.29	10.05	10.10	10.38	10.32
Al ₂ O ₃	34.08	33.93	33.59	33.97	33.83	33.90	34.18	33.86	33.70	33.44	33.27	33.35
Cr ₂ O ₃	0.00	0.00	0.00	0.00	0.02	0.00	0.01	0.01	0.01	0.05	0.00	0.00
Bi ₂ O ₃												
Fe ₂ O ₃ *	0.62	0.00	0.34	0.09	0.00	0.12	0.65	0.85	0.16	0.45	0.08	0.18
FeO*	11.78	13.10	8.20	8.86	10.80	11.00	8.03	7.84	10.99	10.63	9.50	9.09
FeO (tot)	12.33	13.10	8.50	8.94	10.80	11.11	8.61	8.61	11.13	11.03	9.57	9.24
MnO	0.14	0.12	0.09	0.09	0.12	0.12	0.08	0.05	0.19	0.10	0.08	0.05
ZnO	0.04	0.06	0.04	0.08	0.00	0.04	0.10	0.07	0.01	0.02	0.00	0.07
MgO	2.85	1.97	5.18	5.04	3.55	3.26	5.44	5.48	3.44	3.82	5.33	5.31
Li 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
CaO	0.54	0.46	0.51	0.58	0.52	0.46	0.69	0.67	0.61	0.69	0.68	0.67
Na ₂ O	1.73	1.79	1.93	1.89	1.77	1.74	1.94	1.85	1.98	1.90	2.06	1.97
K ₂ O	0.03	0.04	0.05	0.05	0.04	0.05	0.03	0.03	0.05	0.05	0.05	0.07
F	0.13	0.09	0.46	0.23	0.23	0.11	0.28	0.21	0.17	0.34	0.20	0.14
Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00
H ₂ O*	3.46	3.40	3.29	3.45	3.38	3.44	3.44	3.45	3.38	3.32	3.49	3.49
-(O=F,Cl)	-0.06	-0.04	-0.19	-0.10	-0.10	-0.05	-0.12	-0.09	-0.07	-0.15	-0.08	-0.06
Total	98.90	98.08	96.95	98.54	97.87	97.49	98.72	98.17	97.28	97.72	99.52	98.81
T Si (apfu)	5.569	5.613	5.593	5.613	5.617	5.601	5.545	5.556	5.479	5.491	5.675	5.648
T Al	0.431	0.387	0.407	0.387	0.383	0.399	0.455	0.444	0.521	0.509	0.325	0.352
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.084	0.073	0.081	0.087	0.091	0.077	0.083	0.090	0.122	0.136	0.077	0.081
Y Al	0.410	0.508	0.365	0.363	0.437	0.468	0.317	0.297	0.351	0.274	0.241	0.269
Y Cr	0.000	0.000	0.000	0.000	0.003	0.000	0.001	0.001	0.001	0.006	0.000	0.000
Y Fe ³⁺	0.079	0.000	0.044	0.011	0.000	0.016	0.082	0.108	0.021	0.058	0.010	0.022
Y Fe ²⁺	1.677	1.889	1.173	1.248	1.545	1.581	1.129	1.108	1.590	1.530	1.330	1.280
Y Mn	0.020	0.017	0.013	0.013	0.018	0.017	0.011	0.007	0.027	0.014	0.011	0.007
Y Zn	0.005	0.007	0.005	0.010	0.000	0.006	0.013	0.009	0.002	0.002	0.000	0.009
Y Mg	0.724	0.505	1.320	1.267	0.906	0.836	1.364	1.379	0.886	0.979	1.331	1.332
Y Li	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
X Ca	0.098	0.085	0.094	0.105	0.095	0.085	0.125	0.121	0.113	0.126	0.122	0.121
X Na	0.570	0.597	0.639	0.618	0.588	0.581	0.633	0.608	0.666	0.635	0.667	0.642
x K	0.007	0.009	0.011	0.010	0.008	0.010	0.006	0.007	0.012	0.011	0.010	0.015
X vac	0.325	0.309	0.257	0.267	0.309	0.324	0.236	0.264	0.209	0.228	0.201	0.222
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.071	0.049	0.250	0.124	0.123	0.059	0.148	0.111	0.091	0.186	0.106	0.074
W Cl	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.004	0.001	0.001
W OH	0.929	0.907	0.750	0.876	0.852	0.941	0.852	0.889	0.906	0.811	0.893	0.925
W O	0.000	0.043	0.000	0.000	0.025	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Classif.	schorl	schorl	dravite	dravite	schorl	schorl	dravite	dravite	schorl	schorl	dravite	dravite

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site	gmatite)				GRANITE-S07		GRANITE - S07 (normal)				GRANITE S08-1	
Comments	"baby peg" core tur: intermediate	"baby peg" core tur: intermediate	"baby peg" core tur: rim	"baby peg" core tur: rim	"Baby peg" border tur	"Baby peg" border tur	"normal" tur: porous core	"normal" tur: porous core	"normal" tur: porous "rim"	"normal" tur: porous "rim"	qz-tur intergrowth, smaller tur core	qz-tur intergrowth, smaller tur core
Point	15t-3	15t-4	15t-5	15t-6	16t-1	16t-2	19t-1	19t-2	19t-3	19t-4	GN8-1	GN8-2
SiO ₂ (wt.%)	32.57	32.93	33.94	33.97	35.55	35.35	33.60	33.16	33.52	34.18	35.98	35.84
TiO ₂	0.36	0.50	0.64	0.68	0.30	0.46	0.76	1.01	0.66	0.54	0.08	0.18
B ₂ O ₃ *	10.11	10.15	10.28	10.26	10.46	10.46	10.34	10.30	10.24	10.37	10.49	10.47
Al ₂ O ₃	33.02	32.87	31.99	31.94	32.89	32.78	34.31	34.30	33.46	32.66	33.71	33.82
Cr ₂ O ₃	0.00	0.02	0.06	0.01	0.01	0.00	0.00	0.00	0.02	0.01	0.04	0.00
Bi ₂ O ₃												
Fe ₂ O ₃ *	1.59	1.28	0.96	0.34	0.00	0.00	0.00	0.00	0.00	0.37	0.00	0.00
FeO*	12.50	12.40	10.31	10.69	7.89	8.74	9.56	10.14	9.00	8.54	8.65	8.37
FeO (tot)	13.93	13.54	11.18	11.00	7.89	8.74	9.56	10.14	9.00	8.88	8.65	8.37
MnO	0.44	0.39	0.25	0.19	0.00	0.06	0.12	0.19	0.04	0.06	0.10	0.05
ZnO	0.07	0.08	0.04	0.06	0.01	0.01	0.05	0.00	0.00	0.00	0.00	0.00
MgO	2.30	2.56	4.69	4.70	6.15	5.75	4.33	3.99	4.91	5.97	4.94	5.04
Li 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
CaO	0.30	0.29	0.47	0.49	0.78	0.69	0.59	0.73	0.59	0.76	0.38	0.38
Na ₂ O	2.09	2.04	2.09	2.16	1.84	1.91	1.82	1.72	1.70	1.92	1.73	1.82
K ₂ O	0.04	0.03	0.03	0.04	0.07	0.05	0.03	0.05	0.02	0.03	0.04	0.06
F	0.25	0.22	0.40	0.25	0.36	0.23	0.20	0.15	0.27	0.44	0.10	0.02
Cl	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00
H ₂ O*	3.37	3.40	3.36	3.42	3.25	3.36	3.38	3.40	3.37	3.37	3.35	3.35
-(O=F,Cl)	-0.11	-0.09	-0.17	-0.10	-0.15	-0.10	-0.08	-0.06	-0.12	-0.19	-0.04	-0.01
Total	98.90	99.07	99.36	99.09	99.40	99.74	99.00	99.07	97.71	99.02	99.55	99.38
T Si (apfu)	5.598	5.639	5.736	5.754	5.904	5.875	5.651	5.593	5.692	5.731	5.964	5.947
T Al	0.402	0.361	0.264	0.246	0.096	0.125	0.349	0.407	0.308	0.269	0.036	0.053
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.046	0.064	0.082	0.086	0.037	0.057	0.096	0.128	0.085	0.068	0.010	0.023
Y Al	0.288	0.272	0.107	0.132	0.341	0.295	0.450	0.412	0.387	0.186	0.551	0.561
Y Cr	0.000	0.003	0.008	0.001	0.001	0.000	0.000	0.000	0.002	0.001	0.005	0.000
Y Fe ³⁺	0.205	0.164	0.122	0.043	0.000	0.000	0.000	0.000	0.000	0.047	0.000	0.000
Y Fe ²⁺	1.798	1.775	1.457	1.515	1.095	1.215	1.344	1.431	1.277	1.198	1.199	1.161
Y Mn	0.065	0.057	0.036	0.027	0.000	0.009	0.017	0.027	0.005	0.008	0.014	0.007
Y Zn	0.009	0.010	0.005	0.007	0.001	0.001	0.007	0.000	0.000	0.000	0.000	0.000
Y Mg	0.590	0.653	1.182	1.188	1.524	1.424	1.087	1.002	1.244	1.492	1.221	1.248
Y Li	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
X Ca	0.056	0.053	0.085	0.090	0.139	0.123	0.106	0.131	0.108	0.136	0.067	0.067
X Na	0.696	0.678	0.685	0.708	0.592	0.614	0.593	0.562	0.561	0.623	0.557	0.584
x K	0.008	0.007	0.006	0.009	0.014	0.010	0.006	0.011	0.005	0.006	0.009	0.013
X vac	0.240	0.261	0.223	0.194	0.255	0.253	0.294	0.296	0.326	0.236	0.367	0.336
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.136	0.118	0.214	0.132	0.191	0.123	0.105	0.079	0.145	0.233	0.051	0.010
W Cl	0.003	0.001	0.000	0.000	0.000	0.001	0.000	0.000	0.005	0.000	0.001	0.000
W OH	0.860	0.882	0.786	0.868	0.604	0.721	0.792	0.823	0.818	0.767	0.708	0.705
W O	0.000	0.000	0.000	0.000	0.205	0.155	0.103	0.097	0.031	0.000	0.240	0.285
Classif.	schorl	schorl	schorl	schorl	dravite	dravite	schorl	schorl	schorl	dravite	dravite	dravite

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site	GRANITE-S08								GRANITE-S09			
Comments	qz-tur intergrowth, smaller tur rim	qz-tur intergrowth, smaller tur rim	qz-tur intergrowth, bigger tur rim	qz-tur intergrowth, bigger tur rim	qz-tur intergrowth, bigger tur core	qz-tur intergrowth, bigger tur core	faintly faintly zoned tur: core	faintly faintly zoned tur: core	faintly faintly zoned tur: rim	faintly faintly zoned tur: rim	black tur	black tur
Point	GN8-3	GN8-4	GN8-5	GN8-6	GN8-7	GN8-8	20t-1	20t-2	20t-3	20t-4	21t-1	21t-2
SiO ₂ (wt.%)	35.12	34.78	35.01	35.35	35.56	35.34	36.32	35.82	35.61	34.73	34.35	34.40
TiO ₂	0.42	0.36	0.35	0.31	0.16	0.10	0.10	0.09	0.35	0.41	0.48	0.58
B ₂ O ₃ *	10.43	10.36	10.46	10.45	10.45	10.43	10.58	10.49	10.51	10.40	10.27	10.33
Al ₂ O ₃	33.16	32.92	33.42	33.25	33.78	33.65	34.21	33.99	33.16	33.07	32.12	32.30
Cr ₂ O ₃	0.03	0.02	0.03	0.00	0.00	0.00	0.00	0.05	0.00	0.03	0.00	0.03
Bi ₂ O ₃												
Fe ₂ O ₃ *	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06
FeO*	8.85	8.99	8.91	8.76	8.42	8.35	8.17	8.27	9.04	8.96	9.37	9.82
FeO (tot)	8.85	8.99	8.91	8.76	8.42	8.35	8.17	8.27	9.04	8.96	9.37	9.87
MnO	0.11	0.09	0.04	0.04	0.09	0.05	0.09	0.08	0.08	0.15	0.10	0.13
ZnO	0.00	0.05	0.01	0.04	0.00	0.06	0.07	0.04	0.05	0.01	0.02	0.00
MgO	5.38	5.33	5.44	5.36	5.09	5.29	5.12	5.05	5.43	5.44	5.45	5.27
Li 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
CaO	0.69	0.72	0.77	0.77	0.40	0.43	0.31	0.38	0.81	0.78	0.82	0.71
Na ₂ O	1.90	1.79	1.96	1.75	1.70	1.56	1.69	1.67	1.83	1.82	1.78	1.83
K ₂ O	0.06	0.07	0.04	0.06	0.04	0.03	0.05	0.04	0.07	0.07	0.07	0.03
F	0.10	0.12	0.28	0.23	0.14	0.10	0.16	0.07	0.19	0.23	0.28	0.42
Cl	0.00	0.01	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
H ₂ O*	3.38	3.41	3.31	3.30	3.37	3.49	3.36	3.39	3.34	3.38	3.36	3.36
-(O=F,Cl)	-0.04	-0.05	-0.12	-0.10	-0.06	-0.04	-0.07	-0.03	-0.08	-0.10	-0.12	-0.18
Total	99.59	98.97	99.92	99.58	99.16	98.83	100.14	99.40	100.39	99.40	98.36	99.12
T Si (apfu)	5.850	5.832	5.817	5.882	5.913	5.888	5.967	5.935	5.889	5.802	5.814	5.787
T Al	0.150	0.168	0.183	0.118	0.087	0.112	0.033	0.065	0.111	0.198	0.186	0.213
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.053	0.046	0.044	0.039	0.021	0.012	0.012	0.011	0.043	0.052	0.061	0.074
Y Al	0.359	0.339	0.360	0.402	0.533	0.497	0.591	0.573	0.351	0.314	0.220	0.192
Y Cr	0.005	0.002	0.004	0.000	0.000	0.000	0.000	0.006	0.000	0.004	0.000	0.004
Y Fe ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.007
Y Fe ²⁺	1.233	1.261	1.238	1.219	1.171	1.163	1.122	1.146	1.251	1.252	1.327	1.382
Y Mn	0.015	0.013	0.005	0.005	0.013	0.006	0.012	0.012	0.012	0.021	0.014	0.019
Y Zn	0.000	0.006	0.001	0.005	0.000	0.008	0.009	0.005	0.006	0.001	0.003	0.000
Y Mg	1.335	1.333	1.348	1.329	1.262	1.314	1.254	1.248	1.338	1.355	1.376	1.322
Y Li	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
X Ca	0.123	0.130	0.137	0.137	0.072	0.076	0.055	0.067	0.143	0.140	0.148	0.129
X Na	0.614	0.582	0.632	0.564	0.547	0.505	0.537	0.536	0.588	0.590	0.585	0.597
x K	0.012	0.015	0.008	0.012	0.008	0.007	0.011	0.009	0.015	0.014	0.015	0.007
X vac	0.251	0.273	0.222	0.287	0.372	0.411	0.397	0.388	0.254	0.256	0.252	0.267
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.051	0.065	0.145	0.119	0.072	0.053	0.081	0.037	0.098	0.121	0.150	0.226
W Cl	0.000	0.003	0.006	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.002
W OH	0.755	0.810	0.665	0.667	0.742	0.874	0.678	0.748	0.687	0.771	0.796	0.772
W O	0.193	0.122	0.185	0.212	0.187	0.073	0.240	0.215	0.215	0.108	0.052	0.000
Classif.	dravite	dravite	dravite	dravite	dravite	dravite	dravite	dravite	dravite	dravite	dravite	schorl

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site	JAN-S01		JUNCT-S02		JUNCT-S02		LENS-S01		LENS-S01			
Comments	tiny tur no zones; mica & kfsp	tiny tur no zones; mica & kfsp	center tur: core	center tur: core	center tur: rim	center tur: rim	border tur (homogeneous)	border tur (homogeneous)	big tur (homogeneous)	big tur (homogeneous)	small tur core	small tur core
Point	55t-1	55t-2	56t-1	56t-2	56t-3	56t-4	57t-1	57t-2	58t-1	58t-2	59t-1	59t-2
SiO ₂ (wt.%)	33.78	34.05	34.96	34.94	35.74	35.24	35.21	35.43	33.76	33.68	34.44	34.81
TiO ₂	0.25	0.33	1.00	0.91	0.87	1.06	0.23	0.26	0.74	0.84	0.81	0.81
B ₂ O ₃ *	10.29	10.36	10.51	10.47	10.62	10.57	10.56	10.61	10.27	10.29	10.44	10.47
Al ₂ O ₃	35.12	35.05	34.90	34.18	33.20	33.14	34.90	35.00	34.21	34.23	34.34	34.15
Cr ₂ O ₃	0.03	0.04	0.05	0.03	0.04	0.00	0.00	0.00	0.01	0.00	0.02	0.00
Bi ₂ O ₃												
Fe ₂ O ₃ *	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO*	13.54	13.89	8.16	8.62	6.03	6.17	6.96	6.90	13.86	14.06	10.11	9.95
FeO (tot)	13.54	13.89	8.16	8.62	6.03	6.17	6.96	6.90	13.86	14.06	10.11	9.95
MnO	0.64	0.71	0.07	0.08	0.13	0.07	0.01	0.01	0.13	0.26	0.08	0.11
ZnO	0.04	0.12	0.08	0.07	0.04	0.03	0.04	0.02	0.06	0.09	0.00	0.02
MgO	0.57	0.58	4.62	4.76	7.31	7.27	5.90	5.95	1.16	1.05	3.74	3.69
Li ₂ O*	0.16	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.12	0.13	0.19
CaO	0.28	0.23	0.63	0.62	1.35	1.37	0.89	0.90	0.15	0.17	0.34	0.39
Na ₂ O	1.60	1.74	1.78	1.76	1.76	1.64	1.53	1.49	1.80	1.82	1.70	1.68
K ₂ O	0.06	0.05	0.06	0.05	0.05	0.05	0.04	0.05	0.05	0.04	0.05	0.03
F	0.19	0.19	0.00	0.17	0.21	0.27	0.21	0.13	0.31	0.35	0.21	0.18
Cl	0.00	0.02	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.00	0.01
H ₂ O*	3.46	3.48	3.24	3.24	3.22	3.24	3.34	3.38	3.40	3.38	3.50	3.52
-(O=F,Cl)	-0.08	-0.08	0.00	-0.07	-0.09	-0.11	-0.09	-0.06	-0.13	-0.15	-0.09	-0.08
Total	99.91	100.90	100.09	99.84	100.47	100.02	99.74	100.07	99.92	100.25	99.80	99.93
T Si (apfu)	5.707	5.713	5.780	5.800	5.852	5.798	5.793	5.807	5.712	5.692	5.732	5.779
T Al	0.293	0.287	0.220	0.200	0.148	0.202	0.207	0.193	0.288	0.308	0.268	0.221
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.031	0.042	0.124	0.114	0.107	0.131	0.028	0.032	0.095	0.106	0.102	0.101
Y Al	0.700	0.642	0.581	0.487	0.257	0.223	0.560	0.566	0.533	0.510	0.468	0.460
Y Cr	0.004	0.005	0.007	0.004	0.005	0.000	0.000	0.000	0.001	0.000	0.003	0.000
Y Fe ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y Fe ²⁺	1.913	1.949	1.129	1.196	0.825	0.849	0.958	0.946	1.960	1.987	1.407	1.382
Y Mn	0.091	0.100	0.010	0.011	0.018	0.010	0.001	0.001	0.019	0.037	0.011	0.015
Y Zn	0.006	0.015	0.010	0.009	0.005	0.004	0.004	0.002	0.008	0.012	0.000	0.002
Y Mg	0.145	0.146	1.139	1.178	1.784	1.784	1.448	1.454	0.294	0.265	0.927	0.914
Y Li	0.109	0.101	0.000	0.000	0.000	0.000	0.000	0.000	0.091	0.083	0.084	0.126
X Ca	0.050	0.042	0.112	0.111	0.236	0.242	0.157	0.157	0.028	0.031	0.060	0.069
X Na	0.523	0.565	0.572	0.568	0.559	0.523	0.488	0.474	0.590	0.596	0.548	0.542
x K	0.012	0.010	0.013	0.010	0.011	0.011	0.009	0.010	0.010	0.009	0.010	0.006
X vac	0.415	0.384	0.303	0.311	0.194	0.224	0.346	0.359	0.372	0.363	0.381	0.383
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.102	0.100	0.000	0.090	0.108	0.140	0.108	0.065	0.164	0.190	0.109	0.096
W Cl	0.001	0.006	0.000	0.000	0.001	0.000	0.003	0.002	0.000	0.004	0.001	0.001
W OH	0.898	0.893	0.576	0.591	0.521	0.560	0.669	0.698	0.836	0.807	0.890	0.902
W O	0.000	0.000	0.424	0.318	0.370	0.300	0.221	0.234	0.000	0.000	0.000	0.000
Classif.	schorl	schorl	dravite	schorl	dravite	dravite	dravite	dravite	schorl	schorl	schorl	schorl

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site	LENS-S01						LENS2-S01		LENS2-S01		LENS2-S01	
Comments	small tur intermediate	small tur intermediate	small tur rim	small tur rim	small tur no zone	small tur no zone	contact tur (homogeneous and porous)	contact tur (homogeneous and porous)	wall tur	wall tur	center tur	center tur
Point	59t-3	59t-4	59t-5	59t-6	60t-1	60t-2	61t-1	61t-2	62t-1	62t-2	63t-1	63t-2
SiO ₂ (wt.%)	35.68	35.75	34.15	34.17	35.29	35.23	35.43	36.22	35.44	35.35	34.78	35.48
TiO ₂	0.78	0.32	0.94	0.92	0.28	0.28	1.00	0.73	0.78	0.88	0.41	0.14
B ₂ O ₃ *	10.59	10.58	10.33	10.37	10.53	10.54	10.57	10.62	10.50	10.46	10.40	10.46
Al ₂ O ₃	32.23	33.23	34.29	34.13	35.08	35.16	32.27	32.41	32.84	32.79	33.43	33.73
Cr ₂ O ₃	0.07	0.02	0.00	0.05	0.00	0.00	0.04	0.02	0.04	0.05	0.00	0.01
Bi ₂ O ₃												
Fe ₂ O ₃ *	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO*	6.62	8.71	11.96	12.87	10.04	9.96	4.68	4.68	7.46	7.01	9.45	9.19
FeO (tot)	6.62	8.71	11.96	12.87	10.04	9.96	4.68	4.68	7.46	7.01	9.45	9.19
MnO	0.00	0.09	0.12	0.22	0.09	0.08	0.02	0.00	0.09	0.08	0.10	0.09
ZnO	0.00	0.02	0.08	0.08	0.00	0.10	0.02	0.00	0.00	0.02	0.00	0.00
MgO	7.30	5.56	1.84	1.82	3.47	3.46	8.71	8.56	6.42	6.47	4.90	4.78
Li ₂ O*	0.16	0.12	0.25	0.15	0.11	0.11	0.00	0.00	0.00	0.00	0.00	0.00
CaO	1.06	0.35	0.20	0.18	0.17	0.18	2.27	2.10	0.95	0.91	0.84	0.38
Na ₂ O	1.80	2.15	1.73	1.83	1.48	1.49	1.34	1.31	1.86	1.80	1.96	1.95
K ₂ O	0.03	0.02	0.03	0.03	0.02	0.02	0.06	0.05	0.03	0.03	0.04	0.05
F	0.51	0.45	0.48	0.45	0.18	0.26	0.35	0.49	0.14	0.24	0.28	0.00
Cl	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00
H ₂ O*	3.41	3.44	3.33	3.36	3.55	3.51	3.11	3.02	3.31	3.22	3.22	3.41
-(O=F,Cl)	-0.21	-0.19	-0.20	-0.19	-0.07	-0.11	-0.15	-0.20	-0.06	-0.10	-0.12	0.00
Total	100.02	100.62	99.54	100.44	100.20	100.28	99.73	100.00	99.81	99.19	99.71	99.68
T Si (apfu)	5.858	5.873	5.745	5.728	5.823	5.811	5.828	5.927	5.865	5.874	5.812	5.898
T Al	0.142	0.127	0.255	0.272	0.177	0.189	0.172	0.073	0.135	0.126	0.188	0.102
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.096	0.039	0.119	0.116	0.034	0.034	0.124	0.090	0.098	0.109	0.051	0.018
Y Al	0.093	0.308	0.543	0.473	0.644	0.646	0.084	0.179	0.268	0.295	0.394	0.506
Y Cr	0.009	0.003	0.000	0.006	0.000	0.000	0.006	0.003	0.005	0.007	0.000	0.001
Y Fe ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y Fe ²⁺	0.908	1.197	1.682	1.805	1.386	1.374	0.644	0.640	1.033	0.974	1.320	1.278
Y Mn	0.000	0.012	0.017	0.031	0.012	0.012	0.003	0.000	0.012	0.011	0.015	0.012
Y Zn	0.000	0.003	0.010	0.010	0.000	0.012	0.003	0.000	0.000	0.002	0.000	0.000
Y Mg	1.787	1.362	0.461	0.454	0.852	0.851	2.137	2.088	1.584	1.602	1.220	1.185
Y Li	0.106	0.076	0.169	0.104	0.071	0.071	0.000	0.000	0.000	0.000	0.000	0.000
X Ca	0.187	0.062	0.036	0.032	0.029	0.032	0.400	0.368	0.168	0.162	0.151	0.068
X Na	0.574	0.686	0.565	0.593	0.473	0.478	0.428	0.417	0.595	0.581	0.636	0.627
x K	0.007	0.004	0.007	0.006	0.004	0.004	0.013	0.010	0.007	0.005	0.009	0.012
X vac	0.233	0.248	0.393	0.368	0.495	0.486	0.159	0.205	0.230	0.252	0.204	0.293
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.265	0.232	0.257	0.239	0.092	0.134	0.182	0.252	0.075	0.124	0.149	0.000
W Cl	0.000	0.000	0.002	0.000	0.000	0.001	0.001	0.000	0.002	0.000	0.002	0.000
W OH	0.735	0.768	0.741	0.761	0.908	0.865	0.411	0.296	0.653	0.572	0.593	0.784
W O	0.000	0.000	0.000	0.000	0.000	0.000	0.407	0.452	0.271	0.304	0.256	0.216
Classif.	dravite	dravite	schorl	schorl	foitite	foitite	dravite	dravite	dravite	dravite	schorl	schorl

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site	LI S01-2											
Comments	greenish tur; outer rim	greenish tur; outer rim	greenish tur; inner rim	greenish tur; inner rim	greenish tur; outer intermediate	greenish tur; outer intermediate	greenish tur; inner intermediate	greenish tur; inner intermediate	greenish tur; outer core	greenish tur; outer core	greenish tur; inner core	greenish tur; inner core
Point	2LI-1	2LI-2	2LI-3	2LI-4	2LI-5	2LI-6	2LI-7	2LI-8	2LI-9	2LI-10	2LI-11	2LI-12
SiO ₂ (wt.%)	36.60	35.99	36.22	36.18	35.78	35.62	35.27	35.32	35.99	35.90	35.77	36.41
TiO ₂	0.11	0.06	0.10	0.10	0.15	0.12	0.22	0.28	0.21	0.24	0.21	0.15
B ₂ O ₃ *	10.75	10.73	10.79	10.77	10.69	10.63	10.59	10.57	10.62	10.57	10.66	10.75
Al ₂ O ₃	39.07	40.04	40.01	39.74	38.73	38.66	37.94	37.89	37.34	37.11	38.92	38.93
Cr ₂ O ₃	0.04	0.04	0.00	0.03	0.00	0.00	0.00	0.04	0.00	0.01	0.00	0.03
Bi ₂ O ₃												
Fe ₂ O ₃ *	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO*	1.58	1.49	1.44	1.69	3.36	3.05	5.48	5.22	4.97	5.10	2.31	2.80
FeO (tot)	1.58	1.49	1.44	1.69	3.36	3.05	5.48	5.22	4.97	5.10	2.31	2.80
MnO	2.12	1.80	2.34	2.31	2.18	2.31	1.41	1.34	1.54	1.33	2.38	2.03
ZnO	0.03	0.06	0.06	0.04	0.06	0.07	0.36	0.37	0.42	0.47	0.13	0.13
MgO	0.00	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01
Li ₂ O*	1.71	1.62	1.60	1.59	1.50	1.46	1.30	1.30	1.41	1.40	1.53	1.54
CaO	0.31	0.23	0.22	0.23	0.25	0.25	0.16	0.14	0.25	0.23	0.32	0.24
Na ₂ O	2.21	2.05	2.14	2.19	2.54	2.31	2.62	2.42	2.52	2.42	2.19	2.20
K ₂ O	0.01	0.00	0.02	0.01	0.02	0.03	0.02	0.02	0.02	0.02	0.03	0.03
F	1.57	1.40	1.58	1.82	1.73	1.35	1.23	1.31	1.70	1.63	1.57	1.65
Cl	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00
H ₂ O*	2.97	3.04	2.97	2.85	2.87	3.02	3.07	3.03	2.86	2.87	2.93	2.93
-(O=F,Cl)	-0.66	-0.59	-0.67	-0.77	-0.73	-0.57	-0.52	-0.55	-0.72	-0.69	-0.66	-0.70
Total	98.43	97.98	98.86	98.81	99.14	98.34	99.17	98.68	99.16	98.63	98.29	99.15
T Si (apfu)	5.917	5.831	5.834	5.840	5.816	5.826	5.785	5.808	5.891	5.905	5.832	5.885
T Al	0.083	0.169	0.166	0.160	0.184	0.174	0.215	0.192	0.109	0.095	0.168	0.115
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.013	0.008	0.012	0.012	0.019	0.014	0.028	0.034	0.026	0.030	0.026	0.018
Y Al	1.361	1.476	1.428	1.399	1.235	1.277	1.122	1.151	1.094	1.100	1.310	1.299
Y Cr	0.005	0.005	0.000	0.003	0.000	0.000	0.000	0.005	0.000	0.001	0.000	0.004
Y Fe ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y Fe ²⁺	0.214	0.202	0.194	0.228	0.457	0.417	0.751	0.718	0.681	0.702	0.315	0.378
Y Mn	0.291	0.247	0.319	0.316	0.300	0.319	0.196	0.186	0.214	0.186	0.329	0.278
Y Zn	0.003	0.007	0.008	0.004	0.007	0.009	0.044	0.044	0.051	0.057	0.015	0.015
Y Mg	0.000	0.002	0.003	0.003	0.004	0.004	0.003	0.003	0.003	0.002	0.002	0.004
Y Li	1.113	1.053	1.035	1.035	0.978	0.959	0.856	0.857	0.931	0.923	1.003	1.004
X Ca	0.054	0.041	0.037	0.040	0.043	0.044	0.028	0.024	0.045	0.041	0.056	0.042
X Na	0.693	0.645	0.669	0.687	0.800	0.733	0.834	0.772	0.800	0.772	0.691	0.689
x K	0.003	0.000	0.005	0.003	0.004	0.006	0.004	0.003	0.005	0.004	0.006	0.006
X vac	0.250	0.315	0.289	0.271	0.154	0.217	0.135	0.200	0.150	0.183	0.247	0.262
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.802	0.716	0.805	0.928	0.892	0.699	0.636	0.682	0.882	0.847	0.811	0.843
W Cl	0.000	0.001	0.000	0.001	0.000	0.005	0.001	0.000	0.000	0.000	0.001	0.001
W OH	0.198	0.283	0.195	0.071	0.108	0.296	0.363	0.318	0.118	0.153	0.188	0.156
W O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Classif.	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site	LI S01-4			LI S01-5								
Comments	largely homogeneous clearish tur; rim	largely homogeneous clearish tur; intermediate	largely homogeneous clearish tur; core	main xtl center inner core	main xtl edge inner core	main xtl edge outer core	main xtl center outer core	main xtl inner intermediate	main xtl center intermediate	main xtl outer intermediate	main xtl rim	bottom large skeletal tourmaline
Point	4LI-1	4LI-2	4LI-3	5LI-1	5LI-2	5LI-3	5LI-4	5LI-5	5LI-6	5LI-7	5LI-8	5LI-9
SiO ₂ (wt.%)	37.94	37.85	38.21	35.86	35.67	35.30	34.25	35.05	34.96	35.07	35.54	37.72
TiO ₂	0.11	0.03	0.13	0.35	0.14	0.50	0.50	0.61	0.52	0.49	0.25	0.04
B ₂ O ₃ *	10.99	10.98	11.07	10.50	10.44	10.47	10.26	10.41	10.43	10.41	10.61	10.93
Al ₂ O ₃	38.59	40.25	40.49	33.92	34.12	33.91	33.57	33.67	33.99	33.89	36.66	36.83
Cr ₂ O ₃	0.00	0.00	0.07	0.02	0.07	0.02	0.00	0.00	0.02	0.00	0.00	0.00
Bi ₂ O ₃												
Fe ₂ O ₃ *	0.98	0.00	0.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.01
FeO*	2.93	1.08	0.98	14.17	13.65	14.42	14.57	14.81	14.66	14.67	9.31	3.50
FeO (tot)	3.81	1.08	1.28	14.17	13.65	14.42	14.57	14.81	14.66	14.67	9.31	5.31
MnO	0.90	0.94	0.70	0.60	0.56	0.74	0.77	0.80	0.90	0.88	1.58	2.73
ZnO	0.17	0.08	0.10	0.09	0.12	0.11	0.10	0.07	0.12	0.12	0.30	0.07
MgO	0.02	0.01	0.01	0.97	0.86	0.80	0.71	0.66	0.51	0.41	0.13	0.01
Li ₂ O*	1.80	1.90	1.91	0.14	0.21	0.19	0.10	0.14	0.17	0.19	0.78	1.57
CaO	0.20	0.23	0.14	0.06	0.02	0.09	0.10	0.07	0.09	0.08	0.10	0.13
Na ₂ O	2.41	2.01	1.92	1.50	1.60	1.86	1.79	1.81	1.88	1.81	2.19	2.59
K ₂ O	0.01	0.03	0.01	0.02	0.03	0.06	0.06	0.06	0.04	0.03	0.03	0.03
F	1.48	1.32	1.25	0.24	0.14	0.47	0.45	0.42	0.27	0.23	0.88	1.29
Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00
H ₂ O*	3.09	3.16	3.23	3.51	3.53	3.39	3.33	3.40	3.47	3.48	3.24	3.16
-(O=F,Cl)	-0.62	-0.56	-0.53	-0.10	-0.06	-0.20	-0.19	-0.18	-0.11	-0.10	-0.37	-0.54
Total	101.00	99.31	100.03	101.86	101.09	102.11	100.36	101.81	101.91	101.68	101.22	102.08
T Si (apfu)	6.000	5.995	6.000	5.939	5.937	5.861	5.801	5.849	5.827	5.855	5.820	6.000
T Al	0.000	0.005	0.000	0.061	0.063	0.139	0.199	0.151	0.173	0.145	0.180	0.000
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.013	0.003	0.015	0.044	0.017	0.063	0.064	0.077	0.066	0.062	0.030	0.005
Y Al	1.193	1.506	1.494	0.560	0.630	0.495	0.503	0.472	0.506	0.523	0.896	0.904
Y Cr	0.000	0.000	0.009	0.003	0.009	0.003	0.000	0.000	0.002	0.000	0.000	0.000
Y Fe ³⁺	0.116	0.000	0.040	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.241
Y Fe ²⁺	0.387	0.143	0.129	1.963	1.900	2.002	2.063	2.068	2.044	2.048	1.275	0.466
Y Mn	0.121	0.127	0.093	0.085	0.079	0.104	0.110	0.114	0.127	0.124	0.219	0.368
Y Zn	0.019	0.010	0.012	0.011	0.015	0.013	0.013	0.009	0.015	0.015	0.037	0.008
Y Mg	0.005	0.002	0.002	0.238	0.213	0.197	0.180	0.164	0.128	0.103	0.031	0.002
Y Li	1.146	1.210	1.208	0.096	0.137	0.124	0.068	0.097	0.113	0.125	0.513	1.006
X Ca	0.035	0.039	0.024	0.011	0.003	0.015	0.018	0.012	0.016	0.015	0.018	0.023
X Na	0.739	0.618	0.586	0.482	0.515	0.597	0.587	0.585	0.607	0.587	0.695	0.798
x K	0.003	0.005	0.002	0.004	0.006	0.013	0.014	0.014	0.008	0.006	0.006	0.006
X vac	0.223	0.337	0.388	0.503	0.476	0.375	0.381	0.390	0.369	0.392	0.281	0.172
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.741	0.663	0.621	0.126	0.076	0.245	0.238	0.220	0.142	0.121	0.456	0.648
W Cl	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.004	0.000
W OH	0.258	0.336	0.379	0.874	0.924	0.754	0.762	0.780	0.857	0.877	0.540	0.352
W O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Classif.	fluor-elbaite	fluor-elbaite	fluor-elbaite	foitite	schorl	schorl	schorl	schorl	schorl	schorl	schorl	fluor-elbaite

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site	LI S01-6											
Comments	top large skeletal tourmaline	tiny skeletal tourmaline on garnet	tiny skeletal tourmaline on garnet	leftmost tourmaline inner core	leftmost tourmaline inner core	leftmost tourmaline outer core	leftmost tourmaline outer core	leftmost tourmaline inner intermediate	leftmost tourmaline inner intermediate	leftmost tourmaline outer intermediate	leftmost tourmaline outer intermediate	leftmost tourmaline inner rim
Point	5LI-10	5LI-12	5LI-13	6LI-1	6LI-2	6LI-3	6LI-4	6LI-5	6LI-6	6LI-7	6LI-8	6LI-9
SiO ₂ (wt.%)	37.10	36.68	37.07	33.69	34.07	35.73	35.84	36.77	36.97	36.82	36.72	37.05
TiO ₂	0.12	0.06	0.00	0.43	0.56	0.41	0.53	0.22	0.22	0.53	0.38	0.35
B ₂ O ₃ *	10.83	10.72	10.75	10.31	10.33	10.67	10.71	10.92	10.93	10.83	10.80	10.81
Al ₂ O ₃	37.33	37.05	36.91	35.41	35.22	37.77	37.92	39.90	39.82	38.87	39.09	38.68
Cr ₂ O ₃	0.00	0.00	0.02	0.04	0.01	0.05	0.03	0.00	0.04	0.04	0.00	0.00
Bi ₂ O ₃												
Fe ₂ O ₃ *	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO*	4.76	4.45	5.44	11.72	11.39	5.29	5.37	2.46	2.37	3.03	3.11	2.94
FeO (tot)	4.76	4.45	5.44	11.72	11.39	5.29	5.37	2.46	2.37	3.03	3.11	2.94
MnO	3.12	3.41	2.84	1.14	1.12	1.39	1.34	1.35	1.20	0.46	0.37	0.74
ZnO	0.00	0.05	0.04	0.14	0.07	0.19	0.24	0.03	0.03	0.00	0.00	0.05
MgO	0.00	0.01	0.01	0.68	0.65	0.38	0.34	0.16	0.12	0.26	0.31	0.28
Li ₂ O*	1.41	1.36	1.29	0.32	0.42	1.29	1.29	1.69	1.74	1.77	1.67	1.71
CaO	0.20	0.23	0.18	0.09	0.09	0.13	0.14	0.37	0.32	0.28	0.16	0.22
Na ₂ O	2.72	2.60	2.41	2.03	2.00	2.51	2.47	2.29	2.31	2.38	2.19	2.25
K ₂ O	0.02	0.04	0.01	0.04	0.05	0.02	0.03	0.01	0.02	0.02	0.04	0.02
F	1.84	1.55	1.42	0.64	0.77	1.67	1.76	1.37	1.78	1.59	1.60	1.59
Cl	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00
H ₂ O*	2.86	2.96	3.03	3.25	3.20	2.89	2.86	3.12	2.92	2.98	2.97	2.98
-(O=F,Cl)	-0.78	-0.65	-0.60	-0.27	-0.32	-0.70	-0.74	-0.58	-0.75	-0.67	-0.67	-0.67
Total	101.56	100.54	100.86	99.67	99.63	99.67	100.13	100.09	100.05	99.21	98.73	99.00
T Si (apfu)	5.952	5.945	5.992	5.681	5.730	5.821	5.814	5.853	5.881	5.908	5.912	5.955
T Al	0.048	0.055	0.008	0.319	0.270	0.179	0.186	0.147	0.119	0.092	0.088	0.045
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.015	0.007	0.000	0.055	0.071	0.050	0.064	0.027	0.027	0.064	0.046	0.043
Y Al	1.011	1.023	1.023	0.718	0.712	1.074	1.065	1.340	1.347	1.258	1.330	1.283
Y Cr	0.000	0.000	0.002	0.005	0.002	0.007	0.004	0.000	0.005	0.005	0.000	0.000
Y Fe ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y Fe ²⁺	0.638	0.604	0.735	1.653	1.603	0.720	0.728	0.327	0.315	0.407	0.418	0.395
Y Mn	0.424	0.469	0.389	0.163	0.159	0.192	0.183	0.182	0.162	0.063	0.050	0.101
Y Zn	0.000	0.006	0.005	0.018	0.009	0.022	0.029	0.004	0.004	0.000	0.000	0.006
Y Mg	0.000	0.002	0.004	0.171	0.162	0.092	0.082	0.038	0.028	0.062	0.073	0.068
Y Li	0.912	0.889	0.842	0.218	0.281	0.843	0.844	1.082	1.112	1.142	1.082	1.104
X Ca	0.034	0.041	0.032	0.016	0.016	0.023	0.025	0.064	0.054	0.048	0.028	0.038
X Na	0.845	0.816	0.756	0.664	0.653	0.794	0.775	0.706	0.712	0.742	0.683	0.701
x K	0.005	0.009	0.003	0.008	0.010	0.004	0.007	0.002	0.004	0.005	0.009	0.004
X vac	0.116	0.134	0.209	0.311	0.321	0.180	0.193	0.228	0.230	0.205	0.280	0.257
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.933	0.796	0.726	0.343	0.408	0.860	0.903	0.691	0.898	0.809	0.814	0.807
W Cl	0.002	0.000	0.003	0.000	0.000	0.000	0.000	0.001	0.002	0.002	0.002	0.000
W OH	0.065	0.204	0.271	0.656	0.592	0.140	0.097	0.309	0.100	0.188	0.184	0.193
W O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Classif.	fluor-elbaite	fluor-elbaite	fluor-elbaite	schorl	schorl	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site												LI S01-7
Comments	leftmost tourmaline inner rim	leftmost tourmaline outer rim	leftmost tourmaline outer rim	tur a little to right of leftmost tur; core	tur a little to right of leftmost tur; core	tur a little to right of leftmost tur; rim	tur a little to right of leftmost tur; rim	"golf club handle" tur core	"golf club handle" tur core	"golf club handle" tur rim	"golf club handle" tur rim	tur to right of garnet
Point	6LI-10	6LI-11	6LI-12	6LI-13	6LI-14	6LI-15	6LI-16	6LI-17	6LI-18	6LI-19	6LI-20	7LI-1
SiO ₂ (wt.%)	37.01	36.70	36.87	36.65	36.71	36.95	37.42	36.29	36.79	36.72	37.56	34.87
TiO ₂	0.53	0.20	0.27	0.17	0.38	0.02	0.14	0.33	0.25	0.13	0.29	0.17
B ₂ O ₃ *	10.80	10.82	10.84	10.85	10.81	10.83	10.97	10.73	10.76	10.78	10.97	10.41
Al ₂ O ₃	38.39	39.47	39.20	39.69	38.76	39.85	40.47	38.34	37.96	38.88	39.67	36.22
Cr ₂ O ₃	0.00	0.03	0.00	0.00	0.04	0.01	0.04	0.00	0.03	0.00	0.00	0.00
Bi ₂ O ₃												
Fe ₂ O ₃ *	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO*	3.01	2.05	2.43	2.27	3.14	1.41	1.32	4.03	4.23	1.87	2.31	8.67
FeO (tot)	3.01	2.05	2.43	2.27	3.14	1.41	1.32	4.03	4.23	1.87	2.31	8.67
MnO	0.57	1.23	1.00	1.13	0.92	1.54	1.21	0.66	0.76	1.82	0.75	1.67
ZnO	0.01	0.07	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.14
MgO	0.31	0.30	0.34	0.33	0.39	0.04	0.09	0.31	0.28	0.05	0.32	0.03
Li ₂ O*	1.76	1.67	1.70	1.68	1.64	1.74	1.78	1.61	1.62	1.78	1.77	0.83
CaO	0.26	0.28	0.23	0.24	0.26	0.17	0.23	0.29	0.31	0.66	0.25	0.18
Na ₂ O	2.30	2.13	2.31	2.32	2.32	2.11	1.94	2.48	2.45	2.10	2.17	2.05
K ₂ O	0.02	0.02	0.02	0.01	0.02	0.02	0.01	0.03	0.02	0.00	0.01	0.05
F	1.40	1.34	1.52	1.27	1.59	1.42	1.30	1.64	1.71	1.41	1.49	0.91
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
H ₂ O*	3.06	3.10	3.02	3.14	2.98	3.07	3.17	2.92	2.90	3.05	3.08	3.16
-(O=F,Cl)	-0.59	-0.56	-0.64	-0.53	-0.67	-0.60	-0.55	-0.69	-0.72	-0.59	-0.63	-0.38
Total	98.83	98.85	99.16	99.22	99.27	98.56	99.55	98.96	99.36	98.70	100.03	98.99
T Si (apfu)	5.958	5.896	5.912	5.871	5.903	5.930	5.929	5.880	5.943	5.923	5.949	5.822
T Al	0.042	0.104	0.088	0.129	0.097	0.070	0.071	0.120	0.057	0.077	0.051	0.178
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.064	0.024	0.033	0.020	0.046	0.002	0.017	0.040	0.031	0.016	0.035	0.022
Y Al	1.241	1.368	1.320	1.363	1.247	1.467	1.487	1.202	1.168	1.314	1.355	0.950
Y Cr	0.000	0.003	0.000	0.000	0.005	0.002	0.005	0.000	0.003	0.000	0.000	0.000
Y Fe ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y Fe ²⁺	0.405	0.275	0.326	0.304	0.422	0.189	0.175	0.547	0.572	0.253	0.306	1.211
Y Mn	0.077	0.167	0.136	0.153	0.125	0.209	0.162	0.090	0.104	0.248	0.101	0.236
Y Zn	0.001	0.008	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.006	0.000	0.017
Y Mg	0.075	0.073	0.082	0.079	0.092	0.010	0.021	0.075	0.067	0.012	0.076	0.008
Y Li	1.137	1.082	1.098	1.080	1.062	1.121	1.133	1.047	1.054	1.151	1.128	0.555
X Ca	0.044	0.049	0.040	0.042	0.044	0.029	0.040	0.050	0.054	0.114	0.042	0.033
X Na	0.719	0.665	0.717	0.720	0.723	0.656	0.596	0.778	0.767	0.656	0.667	0.663
x K	0.004	0.004	0.005	0.003	0.003	0.004	0.002	0.007	0.004	0.000	0.003	0.011
X vac	0.233	0.282	0.239	0.236	0.230	0.311	0.362	0.165	0.176	0.230	0.287	0.293
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.710	0.681	0.772	0.643	0.809	0.719	0.653	0.839	0.871	0.717	0.745	0.481
W Cl	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
W OH	0.289	0.319	0.227	0.357	0.191	0.281	0.347	0.161	0.129	0.283	0.255	0.518
W O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Classif.	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite	schorl

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site												
Comments	tur to right of garnet	rightmost big tourmaline bottom edge	rightmost big tourmaline bottom edge	rightmost big tourmaline center	rightmost big tourmaline center	rightmost big tourmaline top	rightmost big tourmaline top	rightmost tiny tourmaline	rightmost tiny tourmaline	tur to left of garnet	tur to left of garnet	leftmost tur
Point	7LI-2	7LI-3	7LI-4	7LI-5	7LI-6	7LI-7	7LI-8	7LI-9	7LI-10	7LI-11	7LI-12	7LI-13
SiO ₂ (wt.%)	35.06	36.21	35.93	35.05	35.09	34.51	34.46	35.17	35.57	34.48	34.89	34.91
TiO ₂	0.39	0.13	0.22	0.46	0.45	0.32	0.38	0.20	0.14	0.21	0.14	0.20
B ₂ O ₃ *	10.40	10.82	10.76	10.47	10.50	10.42	10.43	10.56	10.59	10.31	10.31	10.36
Al ₂ O ₃	35.39	40.21	39.99	36.59	36.64	36.61	36.47	37.63	37.93	35.37	35.00	35.52
Cr ₂ O ₃	0.03	0.04	0.00	0.02	0.01	0.00	0.05	0.00	0.03	0.00	0.01	0.02
Bi ₂ O ₃												
Fe ₂ O ₃ *	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO*	8.78	1.85	2.06	7.23	7.16	8.06	8.34	6.20	4.08	9.93	8.91	9.03
FeO (tot)	8.78	1.85	2.06	7.23	7.16	8.06	8.34	6.20	4.08	9.93	8.91	9.03
MnO	1.55	1.23	1.31	1.46	1.56	1.58	1.65	1.53	2.11	1.50	1.85	1.79
ZnO	0.10	0.03	0.08	0.17	0.05	0.16	0.18	0.11	0.00	0.02	0.02	0.09
MgO	0.00	0.00	0.01	0.06	0.06	0.06	0.09	0.06	0.02	0.01	0.00	0.01
Li ₂ O*	0.98	1.75	1.66	1.08	1.13	0.94	0.89	1.19	1.44	0.76	0.92	0.83
CaO	0.15	0.43	0.34	0.16	0.18	0.20	0.17	0.20	0.24	0.13	0.07	0.14
Na ₂ O	2.51	2.25	2.16	2.32	2.49	2.38	2.39	2.45	2.55	2.30	2.59	2.23
K ₂ O	0.02	0.01	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02
F	1.15	1.39	1.22	1.16	1.29	1.15	1.17	1.60	1.54	1.06	1.53	1.24
Cl	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00
H ₂ O*	3.04	3.07	3.13	3.06	3.01	3.05	3.04	2.89	2.92	3.05	2.83	2.99
-(O=F,Cl)	-0.48	-0.59	-0.51	-0.49	-0.55	-0.48	-0.49	-0.67	-0.65	-0.45	-0.65	-0.52
Total	99.07	98.86	98.37	98.84	99.09	98.98	99.25	99.14	98.56	98.73	98.46	98.85
T Si (apfu)	5.858	5.816	5.807	5.818	5.810	5.754	5.745	5.789	5.837	5.813	5.881	5.854
T Al	0.142	0.184	0.193	0.182	0.190	0.246	0.255	0.211	0.163	0.187	0.119	0.146
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.050	0.016	0.027	0.058	0.056	0.041	0.047	0.025	0.018	0.027	0.017	0.026
Y Al	0.828	1.428	1.423	0.975	0.960	0.948	0.910	1.091	1.171	0.840	0.833	0.875
Y Cr	0.004	0.005	0.000	0.002	0.002	0.001	0.006	0.000	0.004	0.000	0.001	0.002
Y Fe ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y Fe ²⁺	1.227	0.249	0.279	1.003	0.992	1.124	1.163	0.854	0.560	1.400	1.256	1.267
Y Mn	0.219	0.168	0.179	0.205	0.219	0.224	0.232	0.214	0.293	0.215	0.264	0.254
Y Zn	0.012	0.004	0.009	0.021	0.006	0.020	0.023	0.014	0.000	0.003	0.003	0.011
Y Mg	0.000	0.000	0.002	0.016	0.015	0.014	0.023	0.014	0.005	0.003	0.001	0.003
Y Li	0.661	1.131	1.081	0.721	0.750	0.630	0.596	0.789	0.949	0.512	0.625	0.562
X Ca	0.027	0.075	0.059	0.028	0.032	0.036	0.031	0.036	0.043	0.024	0.012	0.025
X Na	0.813	0.700	0.676	0.747	0.798	0.770	0.773	0.783	0.811	0.752	0.847	0.726
x K	0.005	0.002	0.003	0.007	0.004	0.004	0.004	0.004	0.005	0.007	0.004	0.004
X vac	0.155	0.223	0.262	0.218	0.166	0.190	0.191	0.177	0.141	0.217	0.137	0.245
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.607	0.707	0.624	0.610	0.677	0.606	0.617	0.831	0.802	0.566	0.817	0.659
W Cl	0.000	0.001	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.002	0.000	0.000
W OH	0.393	0.292	0.376	0.390	0.322	0.394	0.382	0.169	0.198	0.431	0.183	0.341
W O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Classif.	fluor-schorl	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-schorl	fluor-schorl	fluor-elbaite	fluor-elbaite	fluor-schorl	fluor-schorl	fluor-schorl

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site	LI2-S01								LI2-S01			
Comments	leftmost tur	tiny skeletal tourmaline	tiny skeletal tourmaline	tiny tur in middle of slide	tiny tur in middle of slide	pink tur with zones defined by porosity:porous and dark in BSE	pink tur with zones defined by porosity:porous and dark in BSE	pink tur with zones defined by porosity: less porous and brighter in BSE	pink tur with zones defined by porosity: less porous and brighter in BSE	blue tur in cleavelandite (slightly zoned & mostly replaced): core	blue tur in cleavelandite (slightly zoned & mostly replaced): core	blue tur in cleavelandite (slightly zoned & mostly replaced): rim
Point	7LI-14	7LI-15	7LI-16	7LI-17	7LI-18	64t-1	64t-2	64t-3	64t-4	65t-1	65t-2	65t-3
SiO ₂ (wt.%)	34.63	34.89	35.44	35.64	35.24	37.14	37.46	36.58	37.12	35.91	35.32	36.59
TiO ₂	0.21	0.29	0.22	0.06	0.14	0.00	0.01	0.00	0.02	0.00	0.00	0.00
B ₂ O ₃ *	10.29	10.36	10.57	10.49	10.47	11.18	11.21	11.01	11.10	10.71	10.64	10.91
Al ₂ O ₃	35.23	35.45	36.53	36.31	36.70	43.80	43.67	42.85	42.76	39.27	39.28	41.34
Cr ₂ O ₃	0.00	0.00	0.00	0.04	0.04	0.00	0.01	0.04	0.04	0.03	0.00	0.03
Bi ₂ O ₃												
Fe ₂ O ₃ *	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO*	8.87	8.55	7.42	6.20	5.93	0.00	0.00	0.00	0.02	2.02	2.93	0.21
FeO (tot)	8.87	8.55	7.42	6.20	5.93	0.00	0.00	0.00	0.02	2.02	2.93	0.21
MnO	1.75	1.98	2.51	1.97	2.05	0.62	0.62	0.87	0.86	2.83	2.25	1.74
ZnO	0.04	0.00	0.09	0.02	0.02	0.00	0.01	0.00	0.02	0.09	0.05	0.04
MgO	0.04	0.02	0.03	0.00	0.00	0.01	0.02	0.00	0.00	0.01	0.00	0.00
Li ₂ O*	0.87	0.91	1.03	1.29	1.25	1.78	1.81	1.79	1.85	1.50	1.44	1.77
CaO	0.15	0.15	0.18	0.12	0.12	0.03	0.03	0.26	0.28	0.20	0.22	0.28
Na ₂ O	2.32	2.35	2.62	2.78	2.69	1.76	1.72	1.69	1.75	2.33	2.40	1.97
K ₂ O	0.04	0.03	0.04	0.04	0.02	0.00	0.01	0.02	0.01	0.03	0.02	0.02
F	1.20	1.06	1.41	1.69	1.75	0.62	0.66	1.07	1.06	1.78	1.69	1.69
Cl	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
H ₂ O*	2.98	3.07	2.98	2.82	2.78	3.56	3.56	3.29	3.32	2.85	2.87	2.96
-(O=F,Cl)	-0.50	-0.45	-0.60	-0.71	-0.74	-0.26	-0.28	-0.45	-0.45	-0.75	-0.71	-0.71
Total	98.09	98.67	100.47	98.74	98.47	100.25	100.50	99.02	99.77	98.82	98.38	98.83
T Si (apfu)	5.851	5.853	5.825	5.903	5.850	5.774	5.807	5.774	5.815	5.827	5.771	5.830
T Al	0.149	0.147	0.175	0.097	0.150	0.226	0.193	0.226	0.185	0.173	0.229	0.170
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.026	0.037	0.027	0.007	0.017	0.000	0.001	0.000	0.002	0.000	0.000	0.000
Y Al	0.866	0.862	0.902	0.993	1.030	1.800	1.786	1.745	1.709	1.339	1.336	1.594
Y Cr	0.000	0.000	0.000	0.005	0.005	0.000	0.002	0.006	0.005	0.003	0.000	0.003
Y Fe ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y Fe ²⁺	1.253	1.200	1.020	0.859	0.823	0.001	0.000	0.000	0.002	0.274	0.400	0.028
Y Mn	0.250	0.281	0.349	0.276	0.288	0.082	0.081	0.116	0.115	0.389	0.311	0.234
Y Zn	0.004	0.000	0.011	0.003	0.003	0.000	0.001	0.000	0.002	0.011	0.006	0.004
Y Mg	0.009	0.006	0.008	0.000	0.000	0.003	0.004	0.000	0.000	0.003	0.000	0.000
Y Li	0.591	0.614	0.683	0.858	0.833	1.114	1.126	1.133	1.164	0.981	0.947	1.136
X Ca	0.027	0.027	0.031	0.021	0.022	0.005	0.004	0.044	0.048	0.035	0.039	0.048
X Na	0.759	0.763	0.834	0.894	0.865	0.529	0.517	0.516	0.532	0.734	0.759	0.610
x K	0.008	0.007	0.008	0.008	0.004	0.001	0.002	0.004	0.002	0.006	0.003	0.003
X vac	0.206	0.203	0.128	0.078	0.108	0.465	0.476	0.436	0.418	0.224	0.199	0.339
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.639	0.563	0.734	0.886	0.921	0.307	0.321	0.535	0.525	0.912	0.874	0.853
W Cl	0.000	0.003	0.001	0.001	0.000	0.001	0.001	0.000	0.003	0.000	0.000	0.001
W OH	0.361	0.435	0.265	0.113	0.079	0.692	0.678	0.465	0.472	0.088	0.126	0.146
W O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Classif.	fluor-schorl	fluor-schorl	fluor-schorl	fluor-elbaite	fluor-elbaite	elbaite	elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site	LI2-S01					LI2-S01					LI2-S02B	
Comments	blue tur in cleavelandite (slightly zoned & mostly replaced): rim	watermelon tourmaline: porous core	watermelon tourmaline: porous core	watermelon tourmaline: solid rim	watermelon tourmaline: solid rim	pink and clear tur: porous core	pink and clear tur: porous core	pink and clear tur: more solid intermediate	pink and clear tur: more solid intermediate	pink and clear tur: rim	pink and clear tur: rim	black tur: core
Point	65t-4	66t-1	66t-2	66t-3	66t-4	67t-1	67t-2	67t-3	67t-4	67t-5	67t-6	68t-1
SiO ₂ (wt.%)	36.52	37.27	37.28	36.83	36.66	37.59	37.43	36.56	36.56	36.67	37.01	35.19
TiO ₂	0.09	0.00	0.01	0.08	0.06	0.00	0.00	0.04	0.00	0.04	0.01	0.59
B ₂ O ₃ *	10.84	11.17	11.16	10.91	10.91	11.23	11.25	10.98	10.98	11.00	11.00	10.54
Al ₂ O ₃	40.19	43.59	43.52	41.13	41.33	43.98	44.19	42.46	42.39	42.39	41.98	33.90
Cr ₂ O ₃	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.00	0.01	0.03	0.00	0.00
Bi ₂ O ₃												
Fe ₂ O ₃ *	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO*	0.71	0.02	0.01	0.84	0.73	0.02	0.00	0.01	0.02	0.03	0.00	8.11
FeO (tot)	0.71	0.02	0.01	0.84	0.73	0.02	0.00	0.01	0.02	0.03	0.00	8.11
MnO	2.29	0.39	0.39	1.18	1.15	0.17	0.16	1.05	0.94	1.04	0.95	0.03
ZnO	0.01	0.02	0.01	0.02	0.01	0.01	0.06	0.00	0.04	0.00	0.00	0.05
MgO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.71
Li ₂ O*	1.75	1.83	1.84	1.75	1.78	1.83	1.84	1.80	1.83	1.84	1.90	0.00
CaO	0.34	0.02	0.04	0.17	0.13	0.04	0.02	0.35	0.44	0.40	0.39	0.55
Na ₂ O	2.15	1.79	1.76	1.89	2.10	1.57	1.74	1.68	1.72	1.77	1.81	1.81
K ₂ O	0.02	0.02	0.03	0.00	0.01	0.00	0.00	0.01	0.00	0.02	0.02	0.04
F	1.47	0.50	0.75	1.31	1.32	0.63	0.47	1.13	1.42	1.44	1.29	0.18
Cl	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
H ₂ O*	3.04	3.61	3.50	3.14	3.14	3.57	3.66	3.25	3.12	3.11	3.18	3.43
-(O=F,Cl)	-0.62	-0.21	-0.32	-0.55	-0.56	-0.27	-0.20	-0.48	-0.60	-0.61	-0.54	-0.08
Total	98.80	100.02	100.00	98.72	98.77	100.37	100.62	98.84	98.88	99.17	99.01	100.06
T Si (apfu)	5.858	5.800	5.805	5.868	5.838	5.817	5.783	5.787	5.788	5.791	5.847	5.805
T Al	0.142	0.200	0.195	0.132	0.162	0.183	0.217	0.213	0.212	0.209	0.153	0.195
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.011	0.000	0.001	0.010	0.008	0.000	0.000	0.004	0.000	0.005	0.001	0.073
Y Al	1.455	1.797	1.792	1.591	1.596	1.838	1.830	1.710	1.698	1.683	1.665	0.394
Y Cr	0.000	0.001	0.002	0.003	0.000	0.000	0.000	0.000	0.001	0.003	0.001	0.000
Y Fe ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y Fe ²⁺	0.095	0.002	0.001	0.112	0.097	0.002	0.000	0.001	0.003	0.004	0.000	1.119
Y Mn	0.312	0.052	0.052	0.160	0.155	0.023	0.021	0.141	0.126	0.139	0.127	0.004
Y Zn	0.001	0.002	0.001	0.002	0.001	0.001	0.006	0.000	0.004	0.000	0.000	0.006
Y Mg	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.403
Y Li	1.126	1.146	1.150	1.123	1.143	1.136	1.142	1.144	1.167	1.167	1.206	0.000
X Ca	0.059	0.003	0.006	0.030	0.022	0.006	0.004	0.060	0.075	0.067	0.067	0.097
X Na	0.670	0.540	0.530	0.583	0.647	0.470	0.521	0.516	0.529	0.542	0.555	0.580
x K	0.004	0.004	0.006	0.000	0.001	0.000	0.000	0.003	0.000	0.004	0.003	0.009
X vac	0.267	0.454	0.458	0.387	0.329	0.524	0.475	0.421	0.396	0.387	0.375	0.314
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.744	0.248	0.368	0.658	0.665	0.311	0.231	0.568	0.709	0.719	0.647	0.096
W Cl	0.000	0.000	0.001	0.000	0.002	0.000	0.000	0.000	0.001	0.000	0.000	0.003
W OH	0.256	0.752	0.632	0.342	0.333	0.689	0.769	0.432	0.290	0.281	0.353	0.775
W O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.127
Classif.	fluor-elbaite	elbaite	elbaite	fluor-elbaite	fluor-elbaite	rossmanite	elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite	dravite

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site	LI2-S02DE				LI2-S02DE				LI2-S02DE			
Comments	black tur: core	black tur: rim	black tur: rim	core zone green tur: core	core zone green tur: core	core zone green tur: rim	core zone green tur: rim	core zone green tur: core	core zone green tur: core	core zone green tur: rim	core zone green tur: rim	core zone "blue" tur: core
Point	68t-2	68t-3	68t-4	69t-1	69t-2	69t-3	69t-4	70t-1	70t-2	70t-3	70t-4	71t-1
SiO ₂ (wt.%)	35.75	34.79	35.10	37.49	37.52	37.66	37.06	37.12	37.27	37.26	37.17	35.86
TiO ₂	0.42	0.58	0.61	0.07	0.09	0.11	0.10	0.11	0.09	0.09	0.08	0.24
B ₂ O ₃ *	10.57	10.37	10.44	10.92	10.92	11.06	10.97	10.86	10.90	10.96	10.95	10.67
Al ₂ O ₃	33.57	32.30	33.19	39.04	38.93	41.00	40.64	38.96	39.11	40.24	40.25	37.11
Cr ₂ O ₃	0.04	0.09	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.02	0.00	0.00
Bi ₂ O ₃				0.78	0.75	0.43	0.40	0.96	0.95	0.37	0.31	0.01
Fe ₂ O ₃ *	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO*	8.12	9.86	7.92	1.61	1.57	0.90	1.31	2.00	1.89	1.55	1.36	7.19
FeO (tot)	8.12	10.16	7.92	1.61	1.57	0.90	1.31	2.00	1.89	1.55	1.36	7.19
MnO	0.03	0.19	0.03	2.52	2.57	1.21	1.77	1.71	1.84	1.75	1.96	1.19
ZnO	0.12	0.00	0.09	0.10	0.06	0.09	0.10	0.11	0.09	0.11	0.08	0.83
MgO	5.82	5.01	5.84	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.06
Li ₂ O*	0.00	0.00	0.00	1.78	1.80	1.87	1.74	1.84	1.84	1.74	1.73	1.14
CaO	0.46	0.21	0.55	0.17	0.18	0.14	0.14	0.34	0.24	0.12	0.09	0.13
Na ₂ O	1.87	2.05	1.92	2.41	2.47	2.08	2.21	2.35	2.44	2.19	2.23	2.61
K ₂ O	0.05	0.06	0.06	0.02	0.02	0.01	0.01	0.02	0.03	0.02	0.03	0.03
F	0.27	0.36	0.23	1.48	1.52	1.06	1.06	1.37	1.28	1.20	1.07	1.17
Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
H ₂ O*	3.39	3.41	3.33	3.04	3.02	3.30	3.27	3.06	3.12	3.20	3.26	3.13
-(O=F,Cl)	-0.11	-0.15	-0.10	-0.62	-0.64	-0.45	-0.45	-0.58	-0.54	-0.51	-0.45	-0.49
Total	100.37	99.46	99.21	100.81	100.79	100.46	100.35	100.24	100.56	100.31	100.12	100.87
T Si (apfu)	5.877	5.832	5.843	5.966	5.971	5.920	5.869	5.941	5.944	5.908	5.901	5.842
T Al	0.123	0.168	0.157	0.034	0.029	0.080	0.131	0.059	0.056	0.092	0.099	0.158
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.052	0.074	0.077	0.008	0.011	0.013	0.012	0.013	0.011	0.011	0.010	0.029
Y Al	0.383	0.213	0.356	1.287	1.272	1.516	1.455	1.289	1.295	1.427	1.433	0.967
Y Cr	0.005	0.011	0.000	0.000	0.001	0.000	0.001	0.000	0.000	0.003	0.000	0.000
Y Fe ³⁺	0.000	0.042	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y Fe ²⁺	1.117	1.382	1.102	0.214	0.209	0.118	0.174	0.268	0.252	0.206	0.181	0.980
Y Mn	0.004	0.027	0.004	0.340	0.346	0.161	0.237	0.232	0.249	0.235	0.264	0.164
Y Zn	0.015	0.000	0.011	0.012	0.007	0.010	0.012	0.013	0.011	0.013	0.009	0.100
Y Mg	1.425	1.251	1.450	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.002	0.015
Y Li	0.000	0.000	0.000	1.139	1.154	1.181	1.110	1.185	1.181	1.107	1.102	0.745
X Ca	0.082	0.038	0.099	0.029	0.031	0.024	0.024	0.058	0.041	0.020	0.015	0.023
X Na	0.595	0.667	0.621	0.744	0.762	0.634	0.679	0.729	0.754	0.673	0.686	0.824
x K	0.010	0.012	0.012	0.004	0.004	0.002	0.002	0.004	0.006	0.004	0.006	0.006
X vac	0.313	0.283	0.268	0.223	0.203	0.340	0.296	0.208	0.198	0.302	0.292	0.147
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.140	0.192	0.119	0.745	0.765	0.527	0.531	0.693	0.646	0.602	0.537	0.603
W Cl	0.000	0.001	0.000	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000
W OH	0.723	0.808	0.698	0.223	0.204	0.456	0.450	0.267	0.315	0.383	0.450	0.397
W O	0.137	0.000	0.183	0.032	0.031	0.017	0.016	0.040	0.039	0.015	0.013	0.000
Classif.	dravite	schorl	dravite	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site	LI2-S02DE						LI2-S02DE					
Comments	core zone "blue" tur: core	core zone "blue" tur: intermediate	core zone "blue" tur: intermediate	core zone "blue" tur: rim	core zone "blue" tur: rim	core zone homogeneous "blue" tur	core zone homogeneous "blue" tur	core zone black tur: core	core zone black tur: core	core zone black tur: intermediate	core zone black tur: intermediate	core zone black tur: rim
Point	71t-2	71t-3	71t-4	71t-5	71t-6	72t-1	72t-2	73t-1	73t-2	73t-3	73t-4	73t-5
SiO ₂ (wt.%)	36.22	36.64	36.54	37.93	37.68	36.26	35.89	34.81	34.63	36.40	36.40	36.00
TiO ₂	0.26	0.32	0.38	0.07	0.06	0.24	0.26	0.45	0.46	0.37	0.39	0.32
B ₂ O ₃ *	10.70	10.80	10.80	11.07	11.05	10.76	10.71	10.32	10.30	10.69	10.68	10.70
Al ₂ O ₃	36.84	37.70	37.69	40.49	40.87	37.81	37.68	33.27	33.25	36.27	36.18	37.16
Cr ₂ O ₃	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Bi ₂ O ₃	0.02	0.00	0.00	0.45	0.57	0.00	0.00	0.04	0.02	0.02	0.02	0.02
Fe ₂ O ₃ *	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO*	7.73	5.09	5.55	1.26	0.79	6.27	6.57	14.26	14.55	7.70	7.69	6.58
FeO (tot)	7.73	5.09	5.55	1.26	0.79	6.27	6.57	14.26	14.55	7.70	7.69	6.58
MnO	1.14	1.49	1.50	1.09	1.06	1.03	1.03	0.71	0.86	0.82	0.72	1.51
ZnO	0.70	0.42	0.50	0.10	0.03	0.69	0.60	0.09	0.05	0.09	0.07	0.26
MgO	0.07	0.06	0.07	0.01	0.00	0.08	0.09	0.82	0.83	0.49	0.48	0.16
Li ₂ O*	1.10	1.48	1.39	1.92	1.96	1.28	1.24	0.21	0.15	1.21	1.25	1.26
CaO	0.11	0.22	0.21	0.31	0.41	0.13	0.13	0.07	0.09	0.09	0.10	0.17
Na ₂ O	2.49	2.71	2.65	2.12	1.97	2.57	2.63	1.99	1.97	2.74	2.80	2.72
K ₂ O	0.03	0.04	0.03	0.01	0.02	0.06	0.05	0.08	0.06	0.06	0.04	0.08
F	0.95	1.56	1.46	1.47	1.19	1.15	1.11	0.31	0.30	1.22	1.17	1.46
Cl	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.03	0.00	0.00	0.02	0.02
H ₂ O*	3.24	2.99	3.04	3.10	3.23	3.17	3.17	3.40	3.41	3.11	3.12	2.99
-(O=F,Cl)	-0.40	-0.66	-0.61	-0.62	-0.50	-0.49	-0.47	-0.14	-0.13	-0.51	-0.50	-0.62
Total	101.20	100.85	101.20	100.78	100.38	101.02	100.69	100.73	100.81	100.76	100.64	100.81
T Si (apfu)	5.885	5.898	5.879	5.957	5.928	5.856	5.826	5.864	5.841	5.920	5.925	5.848
T Al	0.115	0.102	0.121	0.043	0.072	0.144	0.174	0.136	0.159	0.080	0.075	0.152
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.032	0.039	0.046	0.008	0.007	0.029	0.032	0.057	0.058	0.045	0.048	0.039
Y Al	0.940	1.051	1.025	1.452	1.506	1.053	1.034	0.470	0.451	0.872	0.865	0.963
Y Cr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
Y Fe ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y Fe ²⁺	1.050	0.685	0.747	0.166	0.104	0.847	0.892	2.009	2.052	1.047	1.047	0.894
Y Mn	0.157	0.203	0.204	0.145	0.141	0.141	0.142	0.101	0.123	0.113	0.099	0.208
Y Zn	0.084	0.050	0.059	0.012	0.003	0.082	0.072	0.011	0.006	0.011	0.008	0.031
Y Mg	0.017	0.014	0.017	0.002	0.000	0.019	0.022	0.206	0.209	0.119	0.116	0.039
Y Li	0.720	0.957	0.901	1.215	1.238	0.829	0.807	0.145	0.100	0.792	0.815	0.825
X Ca	0.019	0.038	0.036	0.052	0.069	0.022	0.023	0.013	0.016	0.016	0.017	0.030
X Na	0.784	0.846	0.827	0.646	0.601	0.805	0.828	0.650	0.644	0.864	0.884	0.857
x K	0.006	0.008	0.006	0.002	0.004	0.012	0.010	0.017	0.013	0.012	0.008	0.017
X vac	0.190	0.108	0.131	0.300	0.326	0.160	0.139	0.320	0.327	0.108	0.091	0.097
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.488	0.794	0.743	0.730	0.592	0.587	0.570	0.165	0.160	0.628	0.602	0.750
W Cl	0.000	0.000	0.000	0.000	0.000	0.003	0.003	0.009	0.000	0.000	0.006	0.006
W OH	0.511	0.206	0.257	0.252	0.385	0.410	0.427	0.825	0.839	0.372	0.391	0.244
W O	0.001	0.000	0.000	0.018	0.023	0.000	0.000	0.002	0.001	0.001	0.001	0.001
Classif.	elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite	schorl	schorl	fluor-elbaite	fluor-elbaite	fluor-elbaite

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site	LI2-S02DE										LI2-S02DE	
Comments	core zone blk tur: rim	core zone blk tur: inner core	core zone blk tur: inner core	core zone blk tur: outer core	core zone blk tur: outer core	core zone blk tur: inner intermediate	core zone blk tur: inner intermediate	core zone blk tur: outer intermediate	core zone blk tur: outer intermediate	core zone blk tur: rim	core zone blk tur: rim	greenish tur with lepidolite: core
Point	73t-6	74t-1	74t-2	74t-3	74t-4	74t-5	74t-6	74t-7	74t-8	74t-9	74t-10	75t-1
SiO ₂ (wt.%)	36.20	33.99	34.16	36.02	36.12	35.18	34.91	36.60	36.29	37.23	37.47	37.04
TiO ₂	0.29	0.50	0.50	0.34	0.26	0.37	0.47	0.20	0.21	0.09	0.05	0.01
B ₂ O ₃ *	10.68	10.18	10.23	10.70	10.68	10.57	10.48	10.78	10.80	10.96	10.97	11.05
Al ₂ O ₃	36.86	32.92	33.01	37.21	37.02	36.56	35.80	38.14	38.61	40.44	40.31	42.44
Cr ₂ O ₃	0.00	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00
Bi ₂ O ₃	0.04	0.00	0.00	0.01	0.03	0.01	0.00	0.01	0.01	0.37	0.24	
Fe ₂ O ₃ *	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO*	6.88	14.65	14.79	6.84	6.79	8.81	9.48	3.83	3.85	0.86	0.94	0.96
FeO (tot)	6.88	14.65	14.79	6.84	6.79	8.81	9.48	3.83	3.85	0.86	0.94	0.96
MnO	1.38	0.82	0.82	1.26	1.02	1.28	1.17	1.84	1.85	1.66	1.86	0.57
ZnO	0.31	0.10	0.14	0.23	0.12	0.24	0.16	0.34	0.37	0.01	0.00	0.02
MgO	0.16	0.83	0.83	0.26	0.31	0.32	0.49	0.03	0.02	0.01	0.00	0.00
Li ₂ O*	1.23	0.10	0.10	1.21	1.28	0.88	0.79	1.56	1.52	1.86	1.82	1.74
CaO	0.16	0.09	0.10	0.17	0.16	0.15	0.13	0.28	0.27	0.38	0.23	0.01
Na ₂ O	2.59	2.01	2.02	2.60	2.69	2.43	2.42	2.61	2.63	2.06	2.12	1.90
K ₂ O	0.07	0.04	0.05	0.03	0.03	0.04	0.03	0.02	0.03	0.02	0.04	0.01
F	1.20	0.25	0.29	1.29	1.21	0.88	0.79	1.32	1.36	1.11	1.17	0.68
Cl	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00
H ₂ O*	3.11	3.39	3.39	3.08	3.11	3.23	3.24	3.09	3.08	3.24	3.22	3.49
-(O=F,Cl)	-0.51	-0.11	-0.12	-0.54	-0.51	-0.37	-0.33	-0.56	-0.57	-0.47	-0.49	-0.29
Total	100.67	99.78	100.32	100.71	100.32	100.58	100.03	100.11	100.34	99.85	99.96	99.65
T Si (apfu)	5.889	5.804	5.806	5.850	5.878	5.785	5.791	5.900	5.843	5.904	5.934	5.824
T Al	0.111	0.196	0.194	0.150	0.122	0.215	0.209	0.100	0.157	0.096	0.066	0.176
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.035	0.064	0.064	0.042	0.032	0.046	0.059	0.024	0.025	0.011	0.006	0.001
Y Al	0.956	0.429	0.418	0.973	0.979	0.871	0.791	1.147	1.169	1.462	1.459	1.690
Y Cr	0.000	0.001	0.003	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000
Y Fe ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y Fe ²⁺	0.936	2.092	2.102	0.929	0.924	1.212	1.315	0.516	0.518	0.114	0.125	0.126
Y Mn	0.190	0.119	0.118	0.173	0.141	0.178	0.164	0.251	0.252	0.223	0.250	0.076
Y Zn	0.037	0.013	0.018	0.028	0.014	0.029	0.020	0.040	0.044	0.001	0.000	0.002
Y Mg	0.039	0.211	0.210	0.063	0.075	0.078	0.121	0.007	0.005	0.002	0.000	0.001
Y Li	0.806	0.070	0.067	0.792	0.835	0.585	0.530	1.013	0.985	1.185	1.162	1.103
X Ca	0.028	0.016	0.018	0.030	0.028	0.026	0.023	0.048	0.047	0.065	0.039	0.002
X Na	0.817	0.665	0.666	0.819	0.849	0.775	0.778	0.816	0.821	0.633	0.651	0.579
x K	0.015	0.009	0.011	0.006	0.006	0.008	0.006	0.004	0.006	0.004	0.008	0.002
X vac	0.141	0.309	0.305	0.145	0.117	0.190	0.192	0.132	0.126	0.298	0.302	0.417
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.617	0.135	0.156	0.663	0.623	0.458	0.414	0.673	0.692	0.557	0.586	0.338
W Cl	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.003	0.003	0.000	0.000
W OH	0.378	0.865	0.844	0.337	0.376	0.542	0.586	0.324	0.304	0.425	0.404	0.662
W O	0.002	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.015	0.010	0.000
Classif.	fluor-elbaite	schorl	schorl	fluor-elbaite	fluor-elbaite	schorl	schorl	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite	elbaite

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site	LI2-S03					LONG-S01			LONG-S01			
Comments	greenish tur with lepidolite: core	greenish tur with lepidolite: intermediate	greenish tur with lepidolite: intermediate	greenish tur with lepidolite: rim	greenish tur with lepidolite: rim	black tur (homogeneous)	black tur (homogeneous)	homogeneous contact tur	homogeneous contact tur	core tur: core	core tur: core	core tur: intermediate
Point	75t-2	75t-3	75t-4	75t-5	75t-6	76t-1	76t-2	7t-1	7t-2	8t-1	8t-2	8t-3
SiO ₂ (wt.%)	37.16	36.58	36.42	36.71	36.72	34.60	34.74	34.33	34.21	34.65	33.93	33.77
TiO ₂	0.08	0.00	0.11	0.08	0.04	0.46	0.70	0.49	0.40	0.41	0.56	0.60
B ₂ O ₃ *	11.04	10.85	10.83	10.89	10.88	10.34	10.34	10.47	10.40	10.42	10.41	10.28
Al ₂ O ₃	42.04	40.38	40.49	40.58	40.67	33.15	33.12	34.09	33.95	33.40	33.78	33.67
Cr ₂ O ₃	0.01	0.00	0.00	0.00	0.00	0.02	0.07	0.03	0.00	0.01	0.04	0.01
Bi ₂ O ₃												
Fe ₂ O ₃ *	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO*	0.88	1.88	1.89	1.23	1.08	12.30	11.99	8.00	8.17	8.30	8.01	10.55
FeO (tot)	0.88	1.88	1.89	1.23	1.08	12.30	11.99	8.00	8.17	8.30	8.01	10.55
MnO	0.48	1.31	1.14	1.51	1.50	0.19	0.24	0.02	0.09	0.05	0.05	0.15
ZnO	0.03	0.15	0.14	0.03	0.02	0.01	0.04	0.07	0.00	0.00	0.03	0.05
MgO	0.00	0.02	0.01	0.00	0.01	3.18	3.08	5.86	5.58	5.80	5.93	3.93
Li ₂ O*	1.82	1.66	1.64	1.75	1.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CaO	0.03	0.11	0.11	0.20	0.13	0.13	0.16	0.80	0.75	0.76	0.86	0.45
Na ₂ O	2.04	2.23	2.07	2.20	2.15	2.08	2.00	1.80	1.84	1.87	1.91	1.88
K ₂ O	0.02	0.02	0.01	0.01	0.02	0.03	0.04	0.06	0.04	0.05	0.06	0.05
F	0.70	1.22	1.37	1.37	1.25	0.42	0.22	0.17	0.18	0.24	0.25	0.08
Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
H ₂ O*	3.48	3.16	3.09	3.11	3.16	3.33	3.33	3.47	3.42	3.38	3.41	3.45
-(O=F,Cl)	-0.29	-0.52	-0.58	-0.58	-0.53	-0.18	-0.09	-0.07	-0.07	-0.10	-0.10	-0.03
Total	99.49	99.06	98.73	99.08	98.84	100.06	99.96	99.58	98.97	99.24	99.12	98.89
T Si (apfu)	5.850	5.858	5.845	5.860	5.867	5.816	5.841	5.698	5.717	5.778	5.668	5.707
T Al	0.150	0.142	0.155	0.140	0.133	0.184	0.159	0.302	0.283	0.222	0.332	0.293
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.009	0.000	0.013	0.010	0.004	0.059	0.089	0.061	0.051	0.051	0.070	0.076
Y Al	1.651	1.478	1.502	1.494	1.526	0.383	0.404	0.366	0.404	0.342	0.318	0.413
Y Cr	0.001	0.000	0.000	0.000	0.001	0.003	0.009	0.004	0.000	0.001	0.005	0.002
Y Fe ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y Fe ²⁺	0.116	0.252	0.253	0.164	0.145	1.730	1.686	1.110	1.142	1.157	1.119	1.491
Y Mn	0.064	0.178	0.155	0.204	0.203	0.028	0.033	0.003	0.012	0.007	0.008	0.022
Y Zn	0.004	0.017	0.017	0.004	0.002	0.001	0.005	0.008	0.000	0.000	0.004	0.006
Y Mg	0.000	0.004	0.002	0.000	0.003	0.797	0.772	1.449	1.391	1.441	1.477	0.990
Y Li	1.155	1.071	1.058	1.124	1.116	0.000	0.000	0.000	0.000	0.000	0.000	0.000
X Ca	0.004	0.019	0.019	0.035	0.023	0.023	0.028	0.143	0.135	0.136	0.153	0.082
X Na	0.622	0.693	0.643	0.680	0.665	0.677	0.651	0.579	0.597	0.605	0.619	0.616
x K	0.004	0.003	0.003	0.001	0.004	0.007	0.009	0.012	0.009	0.011	0.013	0.010
X vac	0.370	0.284	0.335	0.284	0.309	0.294	0.312	0.266	0.259	0.247	0.215	0.292
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.348	0.619	0.696	0.692	0.632	0.221	0.117	0.090	0.092	0.128	0.130	0.043
W Cl	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.001	0.000	0.002	0.000
W OH	0.652	0.381	0.304	0.308	0.368	0.729	0.733	0.844	0.807	0.760	0.800	0.893
W O	0.000	0.000	0.000	0.000	0.000	0.049	0.150	0.066	0.099	0.112	0.069	0.063
Classif.	elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite	fluor-elbaite	schorl	schorl	dravite	dravite	dravite	dravite	schorl

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site	MUSC-S01					PEGMA-S01						
Comments	core tur: intermediate	core tur: rim	core tur: rim	core tur: fracture fill	core tur: fracture fill	center tur (black and homogeneous)	center tur (black and homogeneous)	core tur: rim	core tur: rim	core tur: outer intermediate	core tur: outer intermediate	core tur: inner intermediate
Point	8t-4	8t-5	8t-6	8t-7	8t-8	77t-1	77t-2	1t-1	1t-2	1t-3	1t-4	1t-5
SiO ₂ (wt.%)	34.17	33.39	33.27	34.52	33.59	34.41	34.07	34.60	34.75	34.46	34.57	34.54
TiO ₂	0.65	0.30	0.52	0.35	0.47	0.48	0.55	0.52	0.57	0.57	0.54	0.53
B ₂ O ₃ *	10.35	10.15	10.18	10.33	10.23	10.26	10.25	10.46	10.52	10.46	10.43	10.46
Al ₂ O ₃	33.97	32.68	32.82	32.62	32.71	32.64	32.71	33.91	33.99	33.82	33.60	33.74
Cr ₂ O ₃	0.00	0.03	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.03	0.05
Bi ₂ O ₃												
Fe ₂ O ₃ *	0.00	0.72	1.05	0.53	1.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO*	10.35	12.77	12.69	12.23	12.65	9.35	9.44	7.70	7.81	8.74	8.72	9.12
FeO (tot)	10.35	13.42	13.63	12.71	13.74	9.35	9.44	7.70	7.81	8.74	8.72	9.12
MnO	0.10	0.41	0.43	0.21	0.30	0.07	0.05	0.04	0.10	0.11	0.07	0.08
ZnO	0.04	0.09	0.08	0.07	0.08	0.00	0.02	0.00	0.05	0.02	0.00	0.06
MgO	3.90	2.58	2.47	3.38	2.63	4.97	5.03	5.90	5.98	5.42	5.43	5.25
Li 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
CaO	0.41	0.28	0.26	0.37	0.33	0.73	0.73	0.62	0.61	0.51	0.58	0.49
Na ₂ O	1.94	2.08	2.00	1.87	1.88	1.98	1.75	1.88	1.77	1.84	2.02	1.86
K ₂ O	0.06	0.04	0.04	0.05	0.04	0.05	0.07	0.04	0.05	0.03	0.06	0.05
F	0.13	0.37	0.50	0.34	0.47	0.13	0.37	0.39	0.21	0.37	0.07	0.34
Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01
H ₂ O*	3.36	3.33	3.27	3.40	3.31	3.28	3.29	3.32	3.50	3.42	3.45	3.45
-(O=F,Cl)	-0.05	-0.16	-0.21	-0.14	-0.20	-0.06	-0.16	-0.16	-0.09	-0.16	-0.03	-0.14
Total	99.37	99.05	99.36	100.12	99.74	98.29	98.18	99.22	99.81	99.61	99.54	99.85
T Si (apfu)	5.741	5.716	5.682	5.810	5.709	5.831	5.776	5.752	5.741	5.728	5.759	5.738
T Al	0.259	0.284	0.318	0.190	0.291	0.169	0.224	0.248	0.259	0.272	0.241	0.262
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.083	0.038	0.067	0.045	0.060	0.061	0.070	0.065	0.071	0.072	0.068	0.066
Y Al	0.466	0.309	0.286	0.281	0.261	0.349	0.311	0.397	0.358	0.353	0.356	0.344
Y Cr	0.000	0.004	0.000	0.000	0.006	0.000	0.000	0.000	0.000	0.000	0.004	0.006
Y Fe ³⁺	0.000	0.093	0.134	0.067	0.154	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y Fe ²⁺	1.454	1.828	1.812	1.721	1.799	1.325	1.338	1.070	1.079	1.215	1.215	1.267
Y Mn	0.015	0.059	0.063	0.030	0.043	0.010	0.007	0.005	0.014	0.015	0.010	0.011
Y Zn	0.005	0.011	0.010	0.008	0.010	0.000	0.003	0.000	0.006	0.002	0.000	0.007
Y Mg	0.977	0.657	0.629	0.847	0.667	1.256	1.272	1.463	1.472	1.342	1.347	1.300
Y Li	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
X Ca	0.073	0.052	0.047	0.066	0.061	0.132	0.132	0.110	0.108	0.092	0.103	0.088
X Na	0.633	0.690	0.661	0.609	0.621	0.650	0.574	0.607	0.568	0.593	0.653	0.598
x K	0.013	0.008	0.009	0.011	0.009	0.011	0.014	0.009	0.010	0.007	0.012	0.010
X vac	0.281	0.250	0.283	0.314	0.310	0.207	0.279	0.274	0.314	0.309	0.231	0.304
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.067	0.199	0.270	0.182	0.251	0.071	0.197	0.204	0.108	0.196	0.038	0.178
W Cl	0.000	0.000	0.001	0.001	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.002
W OH	0.768	0.801	0.729	0.818	0.749	0.703	0.722	0.681	0.857	0.797	0.836	0.818
W O	0.165	0.000	0.000	0.000	0.000	0.225	0.079	0.115	0.035	0.008	0.127	0.002
Classif.	schorl	schorl	schorl	schorl	schorl	schorl	schorl	dravite	dravite	dravite	dravite	dravite

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site	PEGMA-S01					PEGMA-S02						
Comments	core tur: inner intermediate	core tur: core	core tur: core	black border tur	black border tur	big border tur: outer rim	big border tur: outer rim	big border tur: inner rim	big border tur: inner rim	big border tur: intermediate	big border tur: intermediate	big border tur: core
Point	1t-6	1t-7	1t-8	2t-1	2t-2	5t-1	5t-2	5t-3	5t-4	5t-5	5t-6	5t-7
SiO ₂ (wt.%)	34.52	34.50	34.90	35.46	35.43	34.41	34.53	34.36	34.09	34.77	35.11	35.11
TiO ₂	0.60	0.50	0.46	0.21	0.13	0.63	0.74	0.68	0.75	0.52	0.35	0.35
B ₂ O ₃ *	10.44	10.47	10.52	10.59	10.58	10.41	10.43	10.39	10.36	10.53	10.56	10.54
Al ₂ O ₃	33.54	33.63	33.79	34.62	34.62	33.14	33.35	33.02	33.28	33.68	33.77	33.85
Cr ₂ O ₃	0.01	0.00	0.00	0.02	0.03	0.02	0.00	0.00	0.04	0.02	0.00	0.00
Bi ₂ O ₃												
Fe ₂ O ₃ *	0.40	0.01	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00
FeO*	8.84	7.85	7.88	6.57	6.57	9.59	9.25	10.99	11.96	6.96	6.96	6.66
FeO (tot)	9.20	7.86	7.88	6.57	6.57	9.60	9.25	10.99	11.96	6.96	6.96	6.66
MnO	0.09	0.11	0.04	0.02	0.06	0.14	0.12	0.16	0.18	0.05	0.00	0.05
ZnO	0.04	0.00	0.00	0.00	0.06	0.00	0.05	0.00	0.03	0.00	0.03	0.02
MgO	5.23	6.16	6.11	6.31	6.27	5.21	5.23	4.38	3.59	6.80	6.80	6.76
Li 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
CaO	0.49	0.65	0.62	0.39	0.47	0.50	0.51	0.51	0.46	0.89	0.85	0.89
Na ₂ O	1.69	1.86	1.87	1.55	1.49	1.98	1.99	1.94	1.91	2.03	1.90	1.79
K ₂ O	0.04	0.06	0.04	0.02	0.04	0.05	0.02	0.06	0.09	0.06	0.05	0.04
F	0.17	0.31	0.32	0.18	0.15	0.56	0.44	0.36	0.29	0.36	0.33	0.18
Cl	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.00
H ₂ O*	3.52	3.47	3.43	3.54	3.54	3.33	3.33	3.41	3.43	3.34	3.39	3.43
-(O=F,Cl)	-0.07	-0.13	-0.14	-0.08	-0.07	-0.23	-0.19	-0.15	-0.12	-0.15	-0.14	-0.07
Total	99.55	99.44	99.86	99.40	99.39	99.74	99.81	100.09	100.34	99.86	99.97	99.58
T Si (apfu)	5.746	5.727	5.766	5.821	5.822	5.744	5.752	5.750	5.717	5.739	5.777	5.789
T Al	0.254	0.273	0.234	0.179	0.178	0.256	0.248	0.250	0.283	0.261	0.223	0.211
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.075	0.063	0.057	0.026	0.016	0.079	0.093	0.086	0.094	0.064	0.043	0.043
Y Al	0.327	0.306	0.345	0.520	0.526	0.263	0.298	0.262	0.294	0.291	0.327	0.368
Y Cr	0.002	0.000	0.000	0.003	0.004	0.002	0.000	0.000	0.006	0.002	0.000	0.000
Y Fe ³⁺	0.050	0.001	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000
Y Fe ²⁺	1.231	1.090	1.088	0.903	0.903	1.338	1.288	1.537	1.677	0.961	0.958	0.919
Y Mn	0.013	0.015	0.006	0.003	0.008	0.020	0.016	0.023	0.026	0.007	0.000	0.007
Y Zn	0.005	0.001	0.000	0.000	0.007	0.000	0.006	0.000	0.004	0.000	0.004	0.002
Y Mg	1.298	1.524	1.504	1.545	1.536	1.296	1.298	1.092	0.899	1.673	1.668	1.661
Y Li	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
X Ca	0.087	0.115	0.110	0.068	0.082	0.089	0.092	0.091	0.082	0.157	0.149	0.156
X Na	0.544	0.599	0.600	0.492	0.476	0.642	0.643	0.629	0.620	0.651	0.606	0.573
x K	0.008	0.012	0.008	0.003	0.009	0.010	0.005	0.012	0.020	0.012	0.011	0.008
X vac	0.361	0.274	0.282	0.437	0.433	0.259	0.261	0.268	0.278	0.180	0.234	0.263
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.087	0.162	0.168	0.094	0.080	0.294	0.234	0.189	0.155	0.188	0.173	0.092
W Cl	0.000	0.000	0.000	0.000	0.002	0.000	0.001	0.003	0.001	0.000	0.001	0.000
W OH	0.913	0.838	0.779	0.880	0.885	0.706	0.699	0.802	0.835	0.672	0.720	0.772
W O	0.000	0.000	0.053	0.027	0.032	0.000	0.067	0.006	0.009	0.140	0.105	0.136
Classif.	dravite	dravite	dravite	dravite	dravite	schorl	dravite	schorl	schorl	dravite	dravite	dravite

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site	PEGMA-S02					POCKET-S01				POCKET-S01		
Comments	big border tur: core	tiny border tur: core	tiny border tur: core	tiny border tur: rim	tiny border tur: rim	core tur: core	core tur: core	core tur: rim	core tur: rim	tur, doesn't appear zoned	tur, doesn't appear zoned	fine grained tur: core
Point	5t-8	5t-9	5t-10	5t-11	5t-12	6t-1	6t-2	6t-3	6t-4	78t-1	78t-2	79t-1
SiO ₂ (wt.%)	34.92	34.07	33.81	34.61	34.68	34.53	34.43	34.06	34.15	34.01	33.72	35.22
TiO ₂	0.39	0.35	0.47	0.49	0.70	0.51	0.69	0.57	0.68	0.25	0.27	0.69
B ₂ O ₃ *	10.57	10.29	10.23	10.45	10.41	10.27	10.28	10.27	10.26	10.14	10.09	10.45
Al ₂ O ₃	34.08	31.74	31.71	31.16	31.19	32.81	32.79	33.89	32.84	34.15	33.90	34.57
Cr ₂ O ₃	0.02	0.02	0.00	0.05	0.00	0.04	0.00	0.00	0.01	0.00	0.00	0.02
Bi ₂ O ₃												0.00
Fe ₂ O ₃ *	0.00	0.71	0.46	0.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO*	6.73	10.99	10.92	6.43	7.29	11.46	12.30	13.29	13.00	7.92	7.83	9.43
FeO (tot)	6.73	11.62	11.33	7.32	7.29	11.46	12.30	13.29	13.00	7.92	7.83	9.43
MnO	0.05	0.24	0.22	0.03	0.05	0.18	0.18	1.03	0.30	0.08	0.13	0.07
ZnO	0.06	0.05	0.05	0.00	0.03	0.01	0.00	0.09	0.03	0.02	0.00	0.00
MgO	6.82	4.73	4.71	8.25	7.83	3.54	3.14	1.41	2.70	4.26	4.38	3.88
Li 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
CaO	0.79	0.80	0.80	1.85	1.76	0.29	0.25	0.14	0.23	0.09	0.08	0.40
Na ₂ O	1.82	2.08	2.05	1.41	1.54	2.08	2.02	2.10	2.16	1.46	1.56	1.91
K ₂ O	0.06	0.06	0.05	0.04	0.05	0.05	0.04	0.03	0.05	0.02	0.00	0.05
F	0.18	0.19	0.06	0.37	0.57	0.11	0.11	0.29	0.23	0.15	0.31	0.12
Cl	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
H ₂ O*	3.52	3.46	3.50	3.43	3.28	3.34	3.39	3.24	3.34	3.30	3.22	3.16
-(O=F,Cl)	-0.08	-0.08	-0.03	-0.15	-0.24	-0.05	-0.05	-0.12	-0.10	-0.06	-0.13	-0.05
Total	99.93	99.70	99.01	99.41	99.16	99.17	99.59	100.28	99.87	95.79	95.38	99.93
T Si (apfu)	5.739	5.757	5.747	5.757	5.793	5.844	5.821	5.768	5.785	5.830	5.809	5.855
T Al	0.261	0.243	0.253	0.243	0.207	0.156	0.179	0.232	0.215	0.170	0.191	0.145
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	5.866	5.932	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.048	0.044	0.059	0.061	0.088	0.065	0.088	0.072	0.087	0.032	0.036	0.086
Y Al	0.340	0.078	0.098	0.000	0.000	0.388	0.356	0.531	0.340	0.729	0.693	0.629
Y Cr	0.002	0.003	0.000	0.006	0.000	0.006	0.000	0.000	0.002	0.000	0.000	0.003
Y Fe ³⁺	0.000	0.090	0.059	0.124	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y Fe ²⁺	0.926	1.552	1.552	0.894	1.019	1.622	1.739	1.881	1.842	1.136	1.128	1.311
Y Mn	0.006	0.035	0.031	0.004	0.007	0.026	0.026	0.148	0.043	0.012	0.019	0.010
Y Zn	0.007	0.006	0.006	0.000	0.004	0.001	0.000	0.012	0.003	0.002	0.000	0.000
Y Mg	1.671	1.191	1.193	2.045	1.950	0.892	0.791	0.356	0.682	1.088	1.124	0.962
Y Li	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
X Ca	0.139	0.145	0.145	0.330	0.316	0.052	0.046	0.025	0.041	0.016	0.015	0.071
X Na	0.580	0.681	0.676	0.456	0.500	0.682	0.663	0.688	0.708	0.484	0.520	0.616
x K	0.013	0.013	0.011	0.008	0.011	0.011	0.009	0.007	0.010	0.004	0.001	0.011
X vac	0.269	0.161	0.168	0.205	0.173	0.255	0.282	0.280	0.241	0.496	0.464	0.303
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.092	0.103	0.032	0.192	0.300	0.061	0.060	0.157	0.125	0.080	0.170	0.063
W Cl	0.001	0.000	0.003	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.002	0.000
W OH	0.859	0.897	0.966	0.808	0.657	0.773	0.823	0.654	0.773	0.776	0.703	0.509
W O	0.048	0.000	0.000	0.000	0.044	0.166	0.118	0.188	0.102	0.144	0.125	0.428
Classif.	dravite	schorl	schorl	dravite	dravite	schorl	schorl	schorl	schorl	foitite	schorl	schorl

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site	POCKET-S01			SIMPLE-S01		SIMPLE-S02		SIMPLE2-S01		SIMPLE3-S01		
Comments												
	fine grained tur: core	fine grained tur: rim	fine grained tur: rim	homogeneous border zone tur	homogeneous border zone tur	tiny black tur	tiny black tur	homogeneous black tur	homogeneous black tur	black tur (homogeneous)	black tur (homogeneous)	black tur: core
Point	79t-2	79t-3	79t-4	80t-1	80t-2	81t-1	81t-2	82t-1	82t-2	83t-1	83t-2	138t-1
SiO ₂ (wt.%)	35.04	35.66	35.64	35.87	35.86	34.57	33.95	36.07	35.83	34.50	34.64	35.66
TiO ₂	0.70	0.98	0.98	0.56	0.47	0.63	0.54	0.31	0.31	0.83	0.78	1.12
B ₂ O ₃ *	10.44	10.57	10.58	10.60	10.63	10.41	10.42	10.59	10.51	10.25	10.35	10.54
Al ₂ O ₃	34.56	34.22	34.21	34.25	33.90	33.04	33.53	34.07	33.89	29.98	31.28	30.66
Cr ₂ O ₃	0.01	0.00	0.02	0.01	0.00	0.00	0.04	0.00	0.00	0.04	0.00	0.02
Bi ₂ O ₃	0.00	0.04	0.01	0.02	0.02			0.00	0.02			
Fe ₂ O ₃ *	0.00	0.00	0.00	0.00	0.00	0.00	0.41	0.00	0.00	0.76	0.00	0.00
FeO*	9.42	7.14	7.23	6.09	5.14	8.11	7.72	8.66	8.51	10.17	10.40	6.35
FeO (tot)	9.42	7.14	7.23	6.09	5.14	8.11	8.08	8.66	8.51	10.86	10.40	6.35
MnO	0.06	0.06	0.08	0.03	0.02	0.06	0.04	0.06	0.04	0.13	0.11	0.17
ZnO	0.04	0.00	0.05	0.02	0.02	0.00	0.07	0.02	0.05	0.00	0.00	0.09
MgO	3.92	5.65	5.65	6.48	7.52	6.06	6.16	5.13	5.06	5.88	5.67	8.59
Li 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
CaO	0.37	0.43	0.39	0.79	1.10	0.62	0.79	0.30	0.28	0.70	0.69	1.25
Na ₂ O	1.91	2.09	2.09	1.93	2.06	1.91	1.86	1.79	1.76	2.18	2.23	2.02
K ₂ O	0.05	0.05	0.05	0.05	0.08	0.05	0.05	0.03	0.03	0.06	0.04	0.05
F	0.17	0.09	0.16	0.21	0.14	0.16	0.46	0.18	0.17	0.30	0.31	0.47
Cl	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
H ₂ O*	3.18	3.20	3.21	3.16	3.20	3.47	3.38	3.40	3.37	3.39	3.42	3.33
-(O=F,Cl)	-0.07	-0.04	-0.07	-0.09	-0.06	-0.07	-0.19	-0.08	-0.07	-0.13	-0.13	-0.20
Total	99.80	100.14	100.28	99.99	100.10	99.02	99.23	100.54	99.76	99.05	99.78	100.14
T Si (apfu)	5.833	5.866	5.856	5.883	5.865	5.771	5.662	5.919	5.923	5.852	5.817	5.879
T Al	0.167	0.134	0.144	0.117	0.135	0.229	0.338	0.081	0.077	0.148	0.183	0.121
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	5.845	6.000	5.837
Y Ti	0.088	0.121	0.121	0.069	0.058	0.079	0.068	0.038	0.039	0.106	0.098	0.139
Y Al	0.613	0.501	0.481	0.503	0.400	0.272	0.253	0.508	0.525	0.000	0.007	0.000
Y Cr	0.001	0.000	0.003	0.001	0.000	0.000	0.005	0.000	0.000	0.005	0.000	0.003
Y Fe ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.051	0.000	0.000	0.097	0.000	0.000
Y Fe ²⁺	1.311	0.982	0.994	0.835	0.703	1.132	1.076	1.188	1.176	1.443	1.460	0.875
Y Mn	0.008	0.008	0.011	0.004	0.003	0.008	0.006	0.008	0.006	0.018	0.016	0.024
Y Zn	0.005	0.000	0.006	0.002	0.002	0.000	0.009	0.002	0.006	0.000	0.000	0.012
Y Mg	0.973	1.386	1.384	1.584	1.834	1.508	1.531	1.255	1.247	1.486	1.418	2.111
Y Li	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
X Ca	0.066	0.076	0.069	0.139	0.193	0.111	0.140	0.053	0.050	0.128	0.125	0.221
X Na	0.616	0.667	0.666	0.614	0.653	0.617	0.600	0.569	0.564	0.718	0.724	0.647
x K	0.011	0.010	0.010	0.010	0.017	0.010	0.011	0.006	0.006	0.014	0.008	0.010
X vac	0.307	0.247	0.255	0.237	0.137	0.262	0.248	0.371	0.380	0.140	0.143	0.122
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.089	0.047	0.083	0.109	0.072	0.086	0.242	0.093	0.089	0.163	0.163	0.243
W Cl	0.000	0.000	0.000	0.003	0.000	0.000	0.001	0.000	0.000	0.002	0.001	0.001
W OH	0.528	0.513	0.521	0.461	0.491	0.864	0.757	0.722	0.715	0.835	0.833	0.659
W O	0.382	0.440	0.396	0.427	0.437	0.050	0.000	0.184	0.196	0.000	0.003	0.096
Classif.	schorl	dravite	dravite	dravite	dravite	dravite	dravite	dravite	dravite	dravite	schorl	dravite

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site	SIMPLE 4				SIMPLE 5				SIMPLE6-S01		SIMPLE7-S01	
Comments	black tur: core	black tur: rim	black tur: rim	black tur: core	black tur: core	black tur: rim	black tur: rim	homogeneous black tur	homogeneous black tur	black tur (homogeneous)	black tur (homogeneous)	black tur: core
Point	138t-2	138t-3	138t-4	84t-1	84t-2	84t-3	84t-4	85t-1	85t-2	86t-1	86t-2	87t-1
SiO ₂ (wt.%)	35.15	35.22	35.19	36.24	35.51	35.91	35.43	36.57	35.88	34.44	34.70	36.05
TiO ₂	1.14	1.03	0.80	0.50	0.48	0.86	0.90	0.69	0.78	0.89	0.77	0.32
B ₂ O ₃ *	10.43	10.38	10.33	10.63	10.54	10.45	10.45	10.65	10.55	10.40	10.39	10.58
Al ₂ O ₃	30.39	29.89	29.74	32.69	32.68	30.67	30.98	33.26	33.01	32.05	31.89	34.20
Cr ₂ O ₃	0.06	0.01	0.00	0.03	0.00	0.04	0.01	0.00	0.04	0.00	0.02	0.01
Bi ₂ O ₃												
Fe ₂ O ₃ *	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.00	0.00
FeO*	7.14	8.78	8.78	7.80	7.79	9.08	9.07	6.84	6.96	7.78	8.01	7.61
FeO (tot)	7.14	8.78	8.90	7.80	7.79	9.08	9.07	6.84	6.96	8.06	8.01	7.61
MnO	0.14	0.12	0.11	0.03	0.04	0.14	0.14	0.05	0.02	0.08	0.10	0.04
ZnO	0.00	0.00	0.00	0.07	0.03	0.01	0.01	0.00	0.00	0.00	0.10	0.00
MgO	8.08	7.34	7.24	6.70	6.75	6.53	6.61	6.59	6.59	6.72	6.64	5.57
Li 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
CaO	1.26	1.26	1.12	0.87	0.87	0.81	0.78	0.63	0.64	0.72	0.69	0.52
Na ₂ O	1.98	1.90	1.94	2.01	2.13	2.10	2.12	1.82	2.13	1.96	2.06	1.74
K ₂ O	0.05	0.06	0.05	0.05	0.05	0.05	0.06	0.05	0.06	0.05	0.05	0.06
F	0.39	0.27	0.29	0.27	0.25	0.18	0.24	0.24	0.28	0.26	0.31	0.18
Cl	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00
H ₂ O*	3.34	3.42	3.43	3.33	3.36	3.38	3.44	3.27	3.20	3.46	3.42	3.30
-(O=F,Cl)	-0.17	-0.12	-0.12	-0.12	-0.10	-0.07	-0.10	-0.10	-0.12	-0.11	-0.13	-0.08
Total	99.37	99.58	99.03	101.12	100.38	100.14	100.17	100.55	100.03	99.01	99.02	100.10
T Si (apfu)	5.858	5.895	5.919	5.924	5.852	5.972	5.892	5.971	5.909	5.758	5.806	5.922
T Al	0.142	0.105	0.081	0.076	0.148	0.028	0.108	0.029	0.091	0.242	0.194	0.078
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	5.828	5.792	5.816	6.000	6.000	5.984	5.964	6.000	6.000	6.000	6.000	6.000
Y Ti	0.142	0.130	0.102	0.061	0.060	0.108	0.112	0.085	0.097	0.112	0.097	0.039
Y Al	0.000	0.000	0.000	0.222	0.200	0.000	0.000	0.371	0.318	0.074	0.095	0.544
Y Cr	0.007	0.001	0.000	0.004	0.000	0.005	0.002	0.000	0.005	0.001	0.003	0.002
Y Fe ³⁺	0.000	0.000	0.016	0.000	0.000	0.000	0.000	0.000	0.000	0.039	0.000	0.000
Y Fe ²⁺	0.995	1.228	1.236	1.067	1.073	1.263	1.262	0.935	0.958	1.087	1.122	1.045
Y Mn	0.020	0.016	0.015	0.004	0.005	0.019	0.019	0.006	0.003	0.012	0.015	0.006
Y Zn	0.000	0.000	0.000	0.008	0.004	0.002	0.002	0.000	0.000	0.000	0.012	0.000
Y Mg	2.007	1.832	1.816	1.634	1.658	1.619	1.639	1.603	1.618	1.676	1.656	1.364
Y Li	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
X Ca	0.225	0.227	0.201	0.153	0.154	0.145	0.139	0.109	0.112	0.129	0.124	0.092
X Na	0.639	0.617	0.633	0.638	0.680	0.676	0.685	0.575	0.679	0.635	0.669	0.553
x K	0.011	0.014	0.011	0.011	0.011	0.012	0.013	0.011	0.012	0.010	0.010	0.012
X vac	0.125	0.143	0.156	0.198	0.155	0.167	0.163	0.305	0.196	0.225	0.197	0.343
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.207	0.144	0.155	0.141	0.129	0.092	0.124	0.125	0.143	0.139	0.163	0.093
W Cl	0.000	0.001	0.000	0.004	0.000	0.000	0.002	0.000	0.002	0.001	0.000	0.000
W OH	0.716	0.823	0.844	0.628	0.699	0.753	0.816	0.558	0.512	0.860	0.812	0.612
W O	0.077	0.032	0.000	0.227	0.171	0.155	0.058	0.316	0.343	0.000	0.025	0.295
Classif.	dravite	dravite	dravite	dravite	dravite	dravite	dravite	dravite	dravite	dravite	dravite	dravite

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site	I1 SIMPLE9-S04-1											
Comments	black tur: core	black tur: intermediate	black tur: intermediate	black tur: rim	black tur: rim	tiny tur next to altering cordierite	tiny tur next to altering cordierite	tiny tur next to altering cordierite	middle of the slide tur core	middle of the slide tur core	middle of the slide tur intermediate	middle of the slide tur intermediate
Point	87t-2	87t-3	87t-4	87t-5	87t-6	94S-1	94S-2	94S-3	94S-4	94S-5	94S-6	94S-7
SiO ₂ (wt.%)	35.65	34.22	34.86	34.51	34.36	33.93	33.79	34.42	35.06	34.48	33.96	33.90
TiO ₂	0.21	0.69	0.53	0.26	0.24	0.10	0.28	0.34	0.22	0.26	0.57	0.60
B ₂ O ₃ *	10.56	10.39	10.49	10.33	10.31	10.30	10.23	10.32	10.45	10.39	10.26	10.28
Al ₂ O ₃	34.20	33.20	33.36	33.39	33.82	32.70	32.95	33.28	34.38	34.53	33.58	33.53
Cr ₂ O ₃	0.00	0.03	0.01	0.05	0.00	0.03	0.00	0.00	0.06	0.00	0.00	0.00
Bi ₂ O ₃												
Fe ₂ O ₃ *	0.00	0.00	0.00	0.72	0.18	1.17	0.41	0.00	0.00	0.00	0.00	0.00
FeO*	7.87	8.59	8.61	12.29	11.58	8.75	9.19	9.74	8.32	8.38	10.06	9.43
FeO (tot)	7.87	8.59	8.61	12.93	11.75	9.81	9.56	9.74	8.32	8.38	10.06	9.43
MnO	0.07	0.08	0.11	0.10	0.08	0.12	0.04	0.10	0.12	0.03	0.10	0.09
ZnO	0.00	0.08	0.12	0.00	0.00	0.06	0.00	0.00	0.07	0.06	0.00	0.00
MgO	5.61	5.70	5.75	2.80	3.12	5.35	4.99	4.67	4.91	4.84	4.10	4.62
Li 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
CaO	0.35	0.78	0.76	0.14	0.15	0.42	0.52	0.33	0.28	0.30	0.40	0.45
Na ₂ O	1.95	1.90	1.90	1.68	1.66	2.16	1.81	1.86	1.80	1.68	1.84	2.02
K ₂ O	0.05	0.05	0.05	0.04	0.03	0.03	0.06	0.05	0.03	0.05	0.04	0.04
F	0.15	0.08	0.23	0.12	0.21	0.23	0.26	0.25	0.21	0.19	0.14	0.19
Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00
H ₂ O*	3.41	3.49	3.43	3.51	3.46	3.44	3.41	3.43	3.37	3.43	3.38	3.34
-(O=F,Cl)	-0.06	-0.03	-0.10	-0.05	-0.09	-0.10	-0.11	-0.11	-0.09	-0.08	-0.06	-0.08
Total	100.02	99.25	100.10	99.88	99.11	98.72	97.82	98.70	99.19	98.56	98.39	98.41
T Si (apfu)	5.868	5.723	5.776	5.805	5.795	5.726	5.741	5.796	5.830	5.767	5.750	5.732
T Al	0.132	0.277	0.224	0.195	0.205	0.274	0.259	0.204	0.170	0.233	0.250	0.268
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.026	0.087	0.066	0.033	0.031	0.013	0.035	0.043	0.028	0.033	0.073	0.077
Y Al	0.504	0.266	0.290	0.425	0.516	0.228	0.337	0.399	0.566	0.574	0.452	0.413
Y Cr	0.000	0.004	0.001	0.006	0.000	0.004	0.000	0.000	0.008	0.000	0.000	0.000
Y Fe ³⁺	0.000	0.000	0.000	0.091	0.023	0.149	0.052	0.000	0.000	0.000	0.000	0.000
Y Fe ²⁺	1.084	1.201	1.193	1.729	1.633	1.235	1.306	1.372	1.157	1.172	1.425	1.334
Y Mn	0.010	0.011	0.016	0.014	0.011	0.017	0.006	0.014	0.016	0.004	0.015	0.013
Y Zn	0.000	0.010	0.014	0.000	0.000	0.008	0.000	0.000	0.008	0.008	0.000	0.000
Y Mg	1.377	1.421	1.421	0.702	0.785	1.346	1.263	1.171	1.216	1.208	1.035	1.164
Y Li	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
X Ca	0.061	0.140	0.135	0.025	0.028	0.077	0.095	0.060	0.050	0.054	0.073	0.081
X Na	0.623	0.615	0.610	0.548	0.543	0.707	0.597	0.607	0.580	0.544	0.603	0.662
x K	0.011	0.011	0.011	0.008	0.006	0.006	0.013	0.011	0.007	0.011	0.010	0.009
X vac	0.305	0.234	0.245	0.418	0.424	0.210	0.296	0.322	0.363	0.392	0.314	0.248
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.079	0.040	0.123	0.062	0.110	0.123	0.138	0.132	0.112	0.101	0.072	0.100
W Cl	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.002	0.000
W OH	0.742	0.888	0.788	0.938	0.890	0.877	0.862	0.846	0.741	0.829	0.818	0.769
W O	0.180	0.072	0.089	0.000	0.000	0.000	0.000	0.020	0.147	0.070	0.108	0.131
Classif.	dravite	dravite	dravite	schorl	schorl	dravite	schorl	schorl	dravite	dravite	schorl	schorl

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site	SIMPLE9-S04-3											
Comments	middle of the slide tur inner of main rim	middle of the slide tur inner of main rim	middle of the slide tur outer of main rim	middle of the slide tur outer of main rim	middle of the slide tur tiny outer most rim	middle of the slide tur tiny outer most rim	top left tur core	top left tur core	top left tur rim	top left tur rim	main xtl bottom core	main xtl bottom core
Point	94S-8	94S-9	94S-10	94S-11	94S-12	94S-13	94S3-1	94S3-2	94S3-3	94S3-4	94S3-5	94S3-6
SiO ₂ (wt.%)	32.73	32.75	33.14	33.27	33.94	34.31	35.58	35.72	35.23	34.83	34.88	35.15
TiO ₂	0.70	0.61	0.46	0.54	0.53	0.56	0.35	0.25	0.53	0.54	0.47	0.46
B ₂ O ₃ *	10.11	10.14	10.13	10.14	10.33	10.30	10.52	10.59	10.47	10.38	10.41	10.45
Al ₂ O ₃	33.75	33.93	33.47	33.47	32.85	32.72	33.93	34.24	33.16	33.34	33.10	33.09
Cr ₂ O ₃	0.01	0.00	0.00	0.06	0.02	0.00	0.00	0.05	0.06	0.04	0.03	0.00
Bi ₂ O ₃												
Fe ₂ O ₃ *	0.00	0.00	0.00	0.00	0.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO*	12.73	12.94	11.96	12.00	9.39	9.79	7.97	8.10	9.49	8.85	8.14	8.37
FeO (tot)	12.73	12.94	11.96	12.00	10.21	9.79	7.97	8.10	9.49	8.85	8.14	8.37
MnO	0.19	0.23	0.23	0.17	0.12	0.10	0.07	0.05	0.10	0.06	0.07	0.03
ZnO	0.00	0.02	0.01	0.07	0.05	0.04	0.00	0.07	0.06	0.00	0.05	0.03
MgO	2.26	2.21	2.85	2.72	4.95	4.87	5.55	5.51	5.04	5.10	5.83	5.80
Li 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
CaO	0.44	0.46	0.38	0.35	0.50	0.49	0.41	0.42	0.50	0.50	0.75	0.73
Na ₂ O	1.94	2.03	2.00	1.88	1.89	1.80	1.80	1.74	1.98	1.86	1.93	1.89
K ₂ O	0.04	0.06	0.05	0.06	0.05	0.06	0.04	0.04	0.05	0.05	0.04	0.06
F	0.07	0.19	0.21	0.22	0.30	0.43	0.19	0.27	0.07	0.31	0.19	0.43
Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00
H ₂ O*	3.37	3.33	3.32	3.31	3.42	3.33	3.39	3.40	3.43	3.29	3.34	3.24
-(O=F,Cl)	-0.03	-0.08	-0.09	-0.09	-0.13	-0.18	-0.08	-0.12	-0.03	-0.13	-0.08	-0.18
Total	98.31	98.83	98.12	98.19	99.13	98.61	99.72	100.37	100.13	99.02	99.14	99.55
T Si (apfu)	5.629	5.612	5.688	5.706	5.712	5.792	5.876	5.863	5.851	5.829	5.823	5.846
T Al	0.371	0.388	0.312	0.294	0.288	0.208	0.124	0.137	0.149	0.171	0.177	0.154
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.091	0.079	0.059	0.070	0.067	0.072	0.043	0.031	0.067	0.068	0.059	0.058
Y Al	0.469	0.465	0.459	0.470	0.228	0.303	0.479	0.486	0.341	0.405	0.335	0.333
Y Cr	0.002	0.000	0.000	0.009	0.003	0.000	0.000	0.007	0.007	0.006	0.004	0.000
Y Fe ³⁺	0.000	0.000	0.000	0.000	0.115	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y Fe ²⁺	1.831	1.855	1.717	1.721	1.322	1.382	1.101	1.111	1.318	1.239	1.136	1.164
Y Mn	0.028	0.033	0.034	0.025	0.017	0.015	0.010	0.007	0.014	0.009	0.010	0.005
Y Zn	0.000	0.002	0.001	0.009	0.006	0.004	0.000	0.009	0.007	0.000	0.006	0.004
Y Mg	0.579	0.566	0.730	0.696	1.243	1.225	1.367	1.349	1.247	1.273	1.450	1.438
Y Li	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
X Ca	0.080	0.084	0.070	0.065	0.090	0.088	0.073	0.074	0.090	0.089	0.134	0.129
X Na	0.645	0.676	0.666	0.626	0.617	0.589	0.577	0.554	0.638	0.604	0.623	0.610
x K	0.008	0.013	0.011	0.013	0.011	0.013	0.008	0.009	0.010	0.010	0.009	0.013
X vac	0.267	0.228	0.253	0.296	0.282	0.310	0.342	0.363	0.263	0.298	0.234	0.247
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.040	0.102	0.113	0.118	0.159	0.231	0.098	0.142	0.035	0.165	0.098	0.227
W Cl	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.003	0.002	0.001	0.000	0.001
W OH	0.865	0.806	0.805	0.789	0.841	0.754	0.730	0.726	0.802	0.667	0.722	0.596
W O	0.095	0.091	0.082	0.094	0.000	0.015	0.172	0.129	0.160	0.167	0.179	0.176
Classif.	schorl	schorl	schorl	schorl	schorl	schorl	dravite	dravite	schorl	dravite	dravite	dravite

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site	SIMPLE9-S04-4				contact between pegmatite and host rock							
Comments	main xtl intermediate	main xtl intermediate	main xtl rim	main xtl rim	rightmost homogeneous tur	rightmost homogeneous tur	bottom right zoned tur core	bottom right zoned tur core	bottom right zoned tur rim	bottom right zoned tur rim	bottom right zoned tur skeletal? appendage	bottom right zoned tur skeletal? appendage
Point	94S3-7	94S3-8	94S3-9	94S3-10	94S4-1	94S4-2	94S4-3	94S4-4	94S4-5	94S4-6	94S4-7	94S4-8
SiO ₂ (wt.%)	35.24	34.48	36.05	36.57	35.23	34.76	35.32	35.62	35.02	34.91	34.59	34.83
TiO ₂	0.28	0.51	0.06	0.08	0.57	0.51	0.17	0.24	0.36	0.52	0.48	0.43
B ₂ O ₃ *	10.41	10.29	10.56	10.59	10.46	10.44	10.50	10.57	10.48	10.47	10.35	10.33
Al ₂ O ₃	32.58	33.44	32.91	32.77	32.56	33.55	34.52	34.73	33.75	33.27	33.02	32.38
Cr ₂ O ₃	0.02	0.03	0.01	0.00	0.06	0.07	0.01	0.00	0.00	0.00	0.01	0.02
Bi ₂ O ₃												
Fe ₂ O ₃ *	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO*	9.44	10.19	7.36	7.30	8.57	8.12	7.53	7.57	8.22	8.41	9.94	9.68
FeO (tot)	9.44	10.19	7.36	7.30	8.57	8.12	7.53	7.57	8.22	8.41	9.94	9.68
MnO	0.11	0.05	0.28	0.22	0.03	0.09	0.05	0.06	0.04	0.06	0.16	0.14
ZnO	0.08	0.00	0.04	0.06	0.03	0.00	0.01	0.03	0.05	0.00	0.06	0.04
MgO	5.35	3.98	6.61	6.57	6.05	5.72	5.47	5.43	5.64	5.90	4.65	5.08
Li 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
CaO	0.43	0.31	0.21	0.19	0.76	0.67	0.32	0.36	0.62	0.81	0.42	0.43
Na ₂ O	2.04	1.78	2.16	2.03	1.96	1.95	1.59	1.69	1.88	1.94	1.97	2.16
K ₂ O	0.04	0.06	0.05	0.02	0.05	0.05	0.03	0.03	0.05	0.05	0.05	0.03
F	0.21	0.19	0.42	0.36	0.22	0.18	0.07	0.17	0.25	0.12	0.08	0.53
Cl	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00
H ₂ O*	3.43	3.33	3.41	3.43	3.38	3.37	3.50	3.41	3.36	3.42	3.46	3.20
-(O=F,Cl)	-0.09	-0.08	-0.18	-0.15	-0.09	-0.07	-0.03	-0.07	-0.11	-0.05	-0.03	-0.23
Total	99.59	98.54	99.96	100.04	99.83	99.41	99.08	99.83	99.62	99.84	99.21	99.06
T Si (apfu)	5.881	5.825	5.931	6.000	5.852	5.784	5.844	5.858	5.809	5.794	5.810	5.861
T Al	0.119	0.175	0.069	0.000	0.148	0.216	0.156	0.142	0.191	0.206	0.190	0.139
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.036	0.065	0.008	0.010	0.071	0.064	0.021	0.029	0.045	0.064	0.061	0.055
Y Al	0.289	0.484	0.312	0.337	0.226	0.365	0.577	0.588	0.408	0.300	0.347	0.283
Y Cr	0.003	0.004	0.001	0.000	0.007	0.009	0.002	0.000	0.000	0.000	0.002	0.002
Y Fe ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y Fe ²⁺	1.318	1.439	1.013	1.002	1.191	1.130	1.041	1.041	1.140	1.167	1.396	1.362
Y Mn	0.015	0.007	0.040	0.031	0.004	0.013	0.007	0.008	0.005	0.008	0.023	0.020
Y Zn	0.009	0.000	0.004	0.007	0.004	0.000	0.002	0.004	0.006	0.000	0.008	0.005
Y Mg	1.330	1.002	1.622	1.606	1.497	1.418	1.350	1.330	1.395	1.461	1.164	1.274
Y Li	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
X Ca	0.077	0.055	0.037	0.034	0.136	0.119	0.056	0.063	0.110	0.145	0.076	0.078
X Na	0.661	0.583	0.690	0.645	0.632	0.630	0.509	0.539	0.604	0.624	0.641	0.705
x K	0.008	0.013	0.012	0.004	0.011	0.011	0.007	0.007	0.010	0.010	0.011	0.006
X vac	0.254	0.349	0.262	0.317	0.221	0.240	0.428	0.392	0.276	0.221	0.272	0.210
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.111	0.103	0.220	0.185	0.117	0.092	0.039	0.087	0.132	0.064	0.044	0.284
W Cl	0.002	0.000	0.001	0.000	0.000	0.000	0.001	0.000	0.002	0.002	0.000	0.001
W OH	0.819	0.749	0.743	0.756	0.741	0.742	0.867	0.738	0.723	0.788	0.871	0.592
W O	0.068	0.149	0.035	0.059	0.142	0.166	0.093	0.175	0.143	0.146	0.085	0.123
Classif.	dravite	schorl	dravite	dravite	dravite	dravite	dravite	dravite	dravite	dravite	schorl	schorl

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site												
Comments	center vaguely skeletal tur brown core	center vaguely skeletal tur brown core	center vaguely skeletal tur main intermediate color	center vaguely skeletal tur main intermediate color	center vaguely skeletal tur black core	center vaguely skeletal tur black core	center vaguely skeletal tur blue zone around black core	center vaguely skeletal tur blue zone around black core	center vaguely skeletal tur dark rim	center vaguely skeletal tur dark rim	tur on contact between host and pegmatite	tur on contact between host and pegmatite
Point	94S4-9	94S4-10	94S4-11	94S4-12	94S4-13	94S4-14	94S4-15	94S4-16	94S4-17	94S4-18	94S4-19	94S4-20
SiO ₂ (wt.%)	35.05	34.78	34.67	35.04	35.00	34.87	35.07	35.17	34.76	34.93	35.22	34.58
TiO ₂	0.74	0.81	0.52	0.45	0.73	0.54	0.24	0.38	0.34	0.41	0.52	0.51
B ₂ O ₃ *	10.46	10.40	10.45	10.43	10.35	10.36	10.50	10.56	10.38	10.40	10.47	10.41
Al ₂ O ₃	33.00	32.59	33.53	33.34	31.45	31.67	34.65	34.77	32.84	32.81	33.52	33.18
Cr ₂ O ₃	0.03	0.05	0.00	0.01	0.00	0.06	0.01	0.01	0.00	0.01	0.03	0.04
Bi ₂ O ₃												
Fe ₂ O ₃ *	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO*	8.23	8.19	8.15	8.09	9.39	9.35	7.62	7.87	8.52	8.48	7.90	8.29
FeO (tot)	8.23	8.19	8.15	8.09	9.39	9.35	7.62	7.87	8.52	8.48	7.90	8.29
MnO	0.07	0.02	0.01	0.07	0.10	0.14	0.06	0.08	0.09	0.10	0.03	0.09
ZnO	0.01	0.05	0.04	0.00	0.04	0.00	0.06	0.03	0.02	0.05	0.05	0.01
MgO	5.88	6.03	5.84	5.72	5.84	5.90	5.42	5.41	5.83	5.79	5.77	5.86
Li 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
CaO	0.61	0.70	0.65	0.63	0.63	0.68	0.35	0.36	0.64	0.69	0.68	0.75
Na ₂ O	1.81	2.05	1.79	1.85	1.97	1.97	1.81	1.65	2.06	1.74	1.85	1.83
K ₂ O	0.06	0.07	0.05	0.04	0.05	0.04	0.05	0.04	0.05	0.04	0.07	0.05
F	0.27	0.44	0.25	0.19	0.23	0.25	0.16	0.19	0.25	0.27	0.14	0.20
Cl	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H ₂ O*	3.37	3.21	3.43	3.35	3.41	3.45	3.42	3.49	3.37	3.41	3.35	3.43
-(O=F,Cl)	-0.11	-0.18	-0.11	-0.08	-0.10	-0.10	-0.07	-0.08	-0.10	-0.11	-0.06	-0.08
Total	99.49	99.21	99.28	99.15	99.10	99.17	99.37	99.93	99.05	99.02	99.52	99.15
T Si (apfu)	5.825	5.814	5.769	5.838	5.879	5.852	5.802	5.786	5.818	5.837	5.843	5.773
T Al	0.175	0.186	0.231	0.162	0.121	0.148	0.198	0.214	0.182	0.163	0.157	0.227
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.093	0.102	0.065	0.057	0.092	0.068	0.030	0.048	0.043	0.051	0.065	0.064
Y Al	0.290	0.235	0.344	0.384	0.106	0.115	0.559	0.527	0.296	0.300	0.398	0.300
Y Cr	0.004	0.006	0.000	0.001	0.001	0.008	0.002	0.001	0.000	0.001	0.004	0.005
Y Fe ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y Fe ²⁺	1.144	1.145	1.135	1.127	1.319	1.313	1.054	1.082	1.192	1.185	1.096	1.157
Y Mn	0.010	0.003	0.002	0.010	0.014	0.020	0.009	0.011	0.012	0.014	0.004	0.013
Y Zn	0.002	0.006	0.005	0.000	0.005	0.000	0.008	0.003	0.003	0.006	0.006	0.001
Y Mg	1.458	1.503	1.449	1.421	1.463	1.476	1.338	1.328	1.454	1.443	1.427	1.459
Y Li	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
X Ca	0.109	0.125	0.116	0.113	0.113	0.123	0.061	0.063	0.116	0.123	0.120	0.135
X Na	0.582	0.664	0.576	0.597	0.642	0.643	0.581	0.527	0.667	0.565	0.594	0.593
x K	0.012	0.015	0.010	0.008	0.011	0.008	0.010	0.009	0.011	0.008	0.014	0.011
X vac	0.296	0.196	0.297	0.283	0.234	0.227	0.348	0.401	0.207	0.303	0.272	0.262
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.139	0.231	0.133	0.102	0.123	0.132	0.082	0.098	0.130	0.142	0.072	0.103
W Cl	0.002	0.000	0.000	0.004	0.003	0.000	0.001	0.000	0.000	0.001	0.000	0.000
W OH	0.742	0.582	0.805	0.728	0.825	0.861	0.780	0.830	0.761	0.796	0.704	0.818
W O	0.117	0.188	0.062	0.167	0.049	0.007	0.137	0.072	0.109	0.061	0.224	0.080
Classif.	dravite	dravite	dravite	dravite	dravite	dravite	dravite	dravite	dravite	dravite	dravite	dravite

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site	SIMPLE9-S05-1											
Comments	100 µm 2-zone tur in host rock: core	100 µm 2-zone tur in host rock: rim	~150 µm 4-zone tur in host rock: dark BSE core	~150 µm 4-zone tur in host rock: light BSE core	~150 µm 4-zone tur in host rock: med BSE core	~150 µm 4-zone tur in host rock: rim	main xtl unbleached inner core	main xtl unbleached inner core	main xtl bleached inner core	main xtl bleached inner core	main xtl outer core	main xtl outer core
Point	94S4-21	94S4-22	94S4-23	94S4-24	94S4-25	94S4-26	95S-1	95S-2	95S-3	95S-4	95S-5	95S-6
SiO ₂ (wt.%)	34.95	33.55	35.32	35.47	34.21	34.57	34.90	34.80	34.45	34.63	33.96	34.71
TiO ₂	0.39	0.21	0.40	0.37	0.41	0.27	0.27	0.35	0.32	0.35	0.63	0.69
B ₂ O ₃ *	10.51	10.38	10.48	10.55	10.56	10.45	10.29	10.37	10.26	10.27	10.21	10.27
Al ₂ O ₃	32.41	34.34	31.59	31.96	34.78	33.66	33.19	33.44	33.10	33.07	32.56	32.40
Cr ₂ O ₃	0.01	0.02	0.08	0.05	0.02	0.05	0.00	0.01	0.05	0.00	0.02	0.00
Bi ₂ O ₃												
Fe ₂ O ₃ *	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00
FeO*	5.57	6.99	5.54	6.20	5.51	7.03	11.72	11.84	10.98	11.01	11.79	11.63
FeO (tot)	5.57	6.99	5.54	6.20	5.51	7.03	11.72	11.93	10.98	11.01	11.79	11.63
MnO	0.02	0.03	0.05	0.03	0.05	0.00	0.15	0.26	0.14	0.12	0.14	0.19
ZnO	0.01	0.06	0.09	0.02	0.06	0.01	0.05	0.00	0.04	0.08	0.05	0.00
MgO	8.43	6.38	8.55	8.28	7.35	6.57	3.11	3.25	3.69	3.64	3.56	3.55
Li 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
CaO	2.04	1.09	1.25	2.01	1.46	0.90	0.19	0.16	0.20	0.19	0.33	0.33
Na ₂ O	1.47	1.86	1.77	1.26	1.56	1.91	1.73	1.74	1.75	1.81	1.98	2.07
K ₂ O	0.11	0.06	0.07	0.10	0.06	0.06	0.06	0.04	0.05	0.05	0.04	0.05
F	0.59	0.35	0.67	0.63	0.31	0.18	0.30	0.19	0.11	0.30	0.28	0.20
Cl	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H ₂ O*	3.17	3.35	3.26	3.22	3.38	3.41	3.31	3.49	3.47	3.34	3.36	3.26
-(O=F,Cl)	-0.25	-0.15	-0.28	-0.27	-0.13	-0.08	-0.12	-0.08	-0.04	-0.12	-0.12	-0.08
Total	99.43	98.54	98.84	99.88	99.59	99.01	99.15	99.95	98.54	98.74	98.81	99.27
T Si (apfu)	5.781	5.615	5.860	5.845	5.628	5.750	5.893	5.832	5.835	5.858	5.779	5.876
T Al	0.219	0.385	0.140	0.155	0.372	0.250	0.107	0.168	0.165	0.142	0.221	0.124
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.049	0.026	0.050	0.046	0.050	0.034	0.034	0.044	0.041	0.044	0.080	0.088
Y Al	0.098	0.388	0.037	0.052	0.373	0.349	0.500	0.436	0.443	0.453	0.310	0.342
Y Cr	0.001	0.003	0.010	0.006	0.002	0.007	0.000	0.001	0.006	0.001	0.003	0.000
Y Fe ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.012	0.000	0.000	0.000	0.000
Y Fe ²⁺	0.771	0.979	0.769	0.854	0.758	0.978	1.656	1.659	1.555	1.558	1.678	1.647
Y Mn	0.002	0.004	0.007	0.005	0.007	0.000	0.021	0.036	0.020	0.017	0.021	0.027
Y Zn	0.002	0.007	0.011	0.002	0.007	0.002	0.006	0.000	0.004	0.010	0.006	0.000
Y Mg	2.078	1.593	2.116	2.035	1.803	1.630	0.784	0.811	0.931	0.918	0.902	0.895
Y Li	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
X Ca	0.361	0.196	0.223	0.355	0.257	0.161	0.035	0.029	0.036	0.034	0.060	0.059
X Na	0.473	0.605	0.569	0.401	0.498	0.616	0.568	0.565	0.575	0.595	0.653	0.681
x K	0.022	0.013	0.015	0.022	0.012	0.013	0.012	0.008	0.010	0.011	0.009	0.012
X vac	0.144	0.186	0.194	0.222	0.232	0.211	0.385	0.398	0.379	0.360	0.278	0.248
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.309	0.188	0.353	0.329	0.161	0.094	0.159	0.102	0.056	0.158	0.149	0.107
W Cl	0.000	0.000	0.000	0.004	0.001	0.001	0.000	0.001	0.001	0.000	0.000	0.000
W OH	0.496	0.745	0.610	0.539	0.709	0.782	0.731	0.897	0.921	0.768	0.816	0.687
W O	0.194	0.068	0.036	0.128	0.130	0.124	0.111	0.000	0.022	0.074	0.035	0.206
Classif.	dravite	dravite	dravite	dravite	dravite	dravite	schorl	schorl	schorl	schorl	schorl	schorl

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site												
Comments	main xtl inner rim	main xtl inner rim	main xtl outer rim	main xtl outer rim	leftmost tourmaline core	leftmost tourmaline core	leftmost tourmaline inner intermediate	leftmost tourmaline inner intermediate	leftmost tourmaline outer intermediate	leftmost tourmaline outer intermediate	leftmost tourmaline inner rim	leftmost tourmaline inner rim
Point	95S-7	95S-8	95S-9	95S-10	95S-11	95S-12	95S-13	95S-14	95S-15	95S-16	95S-17	95S-18
SiO ₂ (wt.%)	34.30	33.93	34.07	34.27	34.58	34.59	34.06	34.63	33.94	33.77	33.52	33.73
TiO ₂	0.69	0.76	0.76	0.73	0.61	0.69	0.60	0.82	0.71	0.56	0.35	0.51
B ₂ O ₃ *	10.27	10.16	10.18	10.26	10.35	10.32	10.21	10.38	10.20	10.19	10.14	10.20
Al ₂ O ₃	32.71	32.56	32.48	32.66	32.27	32.26	32.01	32.31	31.91	31.96	32.85	33.16
Cr ₂ O ₃	0.00	0.01	0.00	0.00	0.00	0.05	0.00	0.04	0.02	0.00	0.00	0.05
Bi ₂ O ₃												
Fe ₂ O ₃ *	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.54	0.00	0.00
FeO*	12.13	12.82	13.00	13.48	11.14	10.89	11.18	11.52	11.49	11.01	14.27	14.34
FeO (tot)	12.13	12.82	13.00	13.48	11.21	10.89	11.18	11.52	11.49	11.49	14.27	14.34
MnO	0.24	0.30	0.27	0.36	0.13	0.15	0.09	0.09	0.16	0.12	0.43	0.46
ZnO	0.06	0.07	0.00	0.02	0.02	0.06	0.00	0.01	0.00	0.05	0.04	0.10
MgO	3.26	2.55	2.54	2.46	4.55	4.43	4.29	4.37	4.16	4.28	1.81	1.55
Li 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
CaO	0.28	0.26	0.24	0.26	0.45	0.46	0.41	0.41	0.42	0.41	0.24	0.20
Na ₂ O	1.95	2.09	1.99	1.86	2.05	2.14	2.23	2.09	2.12	2.09	2.10	1.90
K ₂ O	0.06	0.04	0.04	0.06	0.06	0.06	0.07	0.06	0.05	0.04	0.03	0.04
F	0.17	0.17	0.16	0.36	0.15	0.25	0.17	0.25	0.70	0.12	0.20	0.23
Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00
H ₂ O*	3.40	3.29	3.32	3.34	3.50	3.34	3.37	3.44	3.17	3.46	3.39	3.41
-(O=F,Cl)	-0.07	-0.07	-0.07	-0.15	-0.06	-0.10	-0.07	-0.10	-0.30	-0.05	-0.09	-0.10
Total	99.44	98.94	98.99	99.99	99.90	99.58	98.63	100.32	98.77	98.55	99.29	99.79
T Si (apfu)	5.807	5.802	5.820	5.803	5.804	5.827	5.801	5.798	5.781	5.758	5.746	5.748
T Al	0.193	0.198	0.180	0.197	0.196	0.173	0.199	0.202	0.219	0.242	0.254	0.252
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.088	0.097	0.098	0.094	0.077	0.087	0.077	0.103	0.092	0.072	0.045	0.066
Y Al	0.332	0.365	0.358	0.321	0.188	0.232	0.227	0.175	0.189	0.179	0.381	0.409
Y Cr	0.000	0.001	0.000	0.000	0.000	0.007	0.000	0.005	0.003	0.000	0.000	0.007
Y Fe ³⁺	0.000	0.000	0.000	0.000	0.011	0.000	0.000	0.000	0.000	0.069	0.000	0.000
Y Fe ²⁺	1.717	1.834	1.857	1.909	1.563	1.534	1.593	1.613	1.636	1.569	2.045	2.044
Y Mn	0.034	0.044	0.039	0.052	0.019	0.022	0.013	0.013	0.023	0.018	0.062	0.067
Y Zn	0.007	0.008	0.000	0.003	0.003	0.007	0.000	0.001	0.000	0.006	0.005	0.013
Y Mg	0.823	0.651	0.648	0.622	1.139	1.111	1.090	1.090	1.058	1.087	0.461	0.395
Y Li	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
X Ca	0.051	0.047	0.044	0.048	0.082	0.083	0.074	0.074	0.077	0.075	0.044	0.036
X Na	0.640	0.693	0.660	0.612	0.667	0.698	0.737	0.678	0.701	0.692	0.698	0.628
x K	0.014	0.008	0.008	0.012	0.012	0.013	0.016	0.014	0.011	0.009	0.007	0.010
X vac	0.295	0.252	0.287	0.328	0.239	0.206	0.172	0.234	0.212	0.224	0.250	0.327
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.092	0.094	0.088	0.195	0.082	0.131	0.090	0.130	0.378	0.063	0.109	0.123
W Cl	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.000	0.000	0.000	0.002	0.000
W OH	0.838	0.748	0.781	0.775	0.918	0.751	0.824	0.844	0.601	0.937	0.879	0.872
W O	0.069	0.158	0.131	0.030	0.000	0.117	0.085	0.026	0.021	0.000	0.010	0.005
Classif.	schorl	schorl	schorl	schorl	schorl	schorl	schorl	schorl	schorl	schorl	schorl	schorl

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site												
Comments	leftmost tourmaline outer rim; thin rim around xtal 4	leftmost tourmaline outer rim	leftmost tourmaline overgrowth	leftmost tourmaline overgrowth	top right tur inner core	top right tur inner core	top right tur outer core	top right tur outer core	top right tur inner rim	top right tur inner rim	top right tur outer rim	top right tur outer rim (thin rim?)
Point	95S-19	95S-20	95S-21	95S-22	95S-23	95S-24	95S-25	95S-26	95S-27	95S-28	95S-29	95S-30
SiO ₂ (wt.%)	32.96	33.66	33.00	33.47	35.11	34.47	34.91	34.29	34.09	34.18	33.45	33.68
TiO ₂	0.68	0.68	0.74	0.60	0.42	0.47	0.40	0.32	0.82	0.55	0.67	0.80
B ₂ O ₃ *	10.19	10.27	10.19	10.19	10.39	10.29	10.31	10.24	10.25	10.24	10.19	10.26
Al ₂ O ₃	34.43	34.31	34.58	34.06	33.18	33.22	33.18	33.19	32.75	33.18	34.12	34.15
Cr ₂ O ₃	0.02	0.00	0.04	0.01	0.00	0.02	0.00	0.00	0.01	0.02	0.03	0.00
Bi ₂ O ₃												
Fe ₂ O ₃ *	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO*	12.45	12.55	13.02	12.67	12.48	12.27	12.34	12.34	13.38	13.29	12.83	13.09
FeO (tot)	12.45	12.55	13.02	12.67	12.48	12.27	12.34	12.34	13.38	13.29	12.83	13.09
MnO	0.82	0.66	0.95	1.02	0.20	0.22	0.20	0.19	0.23	0.20	0.89	0.80
ZnO	0.07	0.11	0.04	0.10	0.03	0.06	0.01	0.05	0.09	0.07	0.07	0.23
MgO	1.51	1.59	0.84	1.33	3.00	2.91	2.80	2.84	2.50	2.23	1.49	1.51
Li ₂ O*	0.11	0.13	0.15	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CaO	0.11	0.13	0.20	0.14	0.17	0.16	0.18	0.16	0.24	0.22	0.13	0.09
Na ₂ O	2.07	1.91	1.87	1.81	1.88	1.90	1.64	1.83	1.95	1.74	2.00	1.96
K ₂ O	0.03	0.06	0.04	0.03	0.04	0.03	0.03	0.04	0.05	0.07	0.04	0.04
F	0.40	0.56	0.52	0.60	0.02	0.20	0.14	0.23	0.27	0.22	0.50	0.61
Cl	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
H ₂ O*	3.32	3.28	3.27	3.23	3.50	3.40	3.43	3.40	3.36	3.38	3.14	3.15
-(O=F,Cl)	-0.17	-0.24	-0.22	-0.26	-0.01	-0.08	-0.06	-0.10	-0.12	-0.09	-0.21	-0.26
Total	99.02	99.67	99.23	99.11	100.41	99.55	99.52	99.04	99.88	99.49	99.33	100.11
T Si (apfu)	5.623	5.695	5.630	5.706	5.876	5.821	5.884	5.819	5.779	5.802	5.706	5.704
T Al	0.377	0.305	0.370	0.294	0.124	0.179	0.116	0.181	0.221	0.198	0.294	0.296
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.087	0.087	0.095	0.077	0.053	0.059	0.051	0.040	0.104	0.071	0.086	0.102
Y Al	0.545	0.538	0.582	0.551	0.420	0.433	0.475	0.455	0.322	0.440	0.564	0.520
Y Cr	0.003	0.000	0.006	0.001	0.000	0.002	0.001	0.000	0.001	0.002	0.004	0.000
Y Fe ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y Fe ²⁺	1.776	1.776	1.857	1.806	1.746	1.733	1.739	1.751	1.897	1.886	1.830	1.853
Y Mn	0.119	0.095	0.138	0.147	0.028	0.032	0.029	0.028	0.032	0.029	0.129	0.115
Y Zn	0.009	0.014	0.005	0.012	0.004	0.008	0.001	0.006	0.011	0.008	0.009	0.028
Y Mg	0.383	0.400	0.214	0.337	0.749	0.733	0.705	0.719	0.633	0.564	0.378	0.381
Y Li	0.077	0.091	0.105	0.068	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
X Ca	0.020	0.023	0.036	0.026	0.030	0.028	0.032	0.029	0.043	0.040	0.023	0.017
X Na	0.685	0.627	0.617	0.597	0.611	0.624	0.536	0.603	0.641	0.573	0.660	0.643
x K	0.007	0.012	0.009	0.006	0.009	0.007	0.006	0.009	0.011	0.015	0.008	0.008
X vac	0.288	0.338	0.337	0.371	0.350	0.342	0.426	0.360	0.305	0.372	0.309	0.333
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.217	0.300	0.281	0.323	0.009	0.104	0.073	0.123	0.143	0.118	0.269	0.329
W Cl	0.001	0.000	0.000	0.004	0.000	0.001	0.000	0.000	0.003	0.001	0.001	0.001
W OH	0.782	0.700	0.718	0.672	0.908	0.834	0.859	0.853	0.804	0.828	0.570	0.557
W O	0.000	0.000	0.000	0.000	0.083	0.061	0.067	0.024	0.050	0.054	0.160	0.114
Classif.	schorl	schorl	schorl	schorl	schorl	schorl	schorl	schorl	schorl	schorl	schorl	schorl

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site	SIMPLE9-S05 "west"			SIMPLE11-S01		SIMPLE12-S01			SIMPLE12-S01		
Comments	black homogeneous tur	black homogeneous tur	black tur (homogeneous)	black tur (homogeneous)	black border tur: core	black border tur: core	black border tur: rim	black border tur: rim	oscillatory center tur: dark BSE core	oscillatory center tur: dark BSE core	oscillatory center tur: light BSE intermediate
Point	88t-1	88t-2	91t-1	91t-2	92t-1	92t-2	92t-3	92t-4	93t-1	93t-2	93t-3
SiO ₂ (wt.%)	32.82	33.34	34.73	34.42	35.13	34.82	34.16	34.50	35.31	35.30	34.08
TiO ₂	0.78	0.75	0.44	0.37	0.22	0.35	0.71	0.64	0.60	0.60	0.71
B ₂ O ₃ *	10.12	10.17	10.48	10.42	10.43	10.39	10.37	10.40	10.41	10.41	10.23
Al ₂ O ₃	33.02	32.91	33.48	33.50	33.53	33.21	32.87	33.12	33.28	33.24	33.58
Cr ₂ O ₃	0.02	0.00	0.00	0.00	0.04	0.02	0.00	0.08	0.02	0.01	0.01
Bi ₂ O ₃									0.00	0.01	0.00
Fe ₂ O ₃ *	0.79	0.61	0.00	0.00	0.00	0.05	0.14	0.00	0.00	0.00	0.00
FeO*	13.76	13.77	8.24	8.24	9.52	9.57	10.42	10.32	10.47	10.58	15.61
FeO (tot)	14.48	14.32	8.24	8.24	9.52	9.61	10.55	10.32	10.47	10.58	15.61
MnO	0.44	0.40	0.04	0.02	0.19	0.17	0.16	0.17	0.15	0.17	0.26
ZnO	0.02	0.07	0.03	0.00	0.03	0.09	0.03	0.00	0.03	0.04	0.05
MgO	1.71	1.82	6.01	5.92	4.73	4.82	4.78	4.66	4.01	3.96	0.53
Li ₂ O*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CaO	0.22	0.22	0.87	0.87	0.22	0.27	0.57	0.57	0.30	0.30	0.23
Na ₂ O	1.96	1.84	2.02	1.79	1.85	1.85	2.00	1.88	2.00	1.99	1.68
K ₂ O	0.05	0.07	0.07	0.04	0.06	0.04	0.06	0.04	0.03	0.03	0.02
F	0.05	0.30	0.41	0.27	0.16	0.11	0.16	0.21	0.21	0.12	0.06
Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H ₂ O*	3.47	3.37	3.29	3.42	3.49	3.53	3.50	3.46	3.27	3.33	3.39
-(O=F,Cl)	-0.02	-0.13	-0.17	-0.11	-0.07	-0.05	-0.07	-0.09	-0.09	-0.05	-0.03
Total	99.21	99.50	99.92	99.16	99.53	99.25	99.85	99.95	100.01	100.04	100.42
T Si (apfu)	5.634	5.698	5.761	5.741	5.852	5.825	5.724	5.764	5.893	5.892	5.789
T Al	0.366	0.302	0.239	0.259	0.148	0.175	0.276	0.236	0.107	0.108	0.211
B	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.100	0.096	0.055	0.047	0.027	0.044	0.089	0.080	0.075	0.075	0.091
Y Al	0.316	0.326	0.306	0.328	0.437	0.372	0.214	0.283	0.438	0.432	0.512
Y Cr	0.002	0.000	0.000	0.000	0.006	0.002	0.000	0.010	0.003	0.001	0.001
Y Fe ³⁺	0.102	0.078	0.000	0.000	0.000	0.006	0.018	0.000	0.000	0.000	0.000
Y Fe ²⁺	1.976	1.968	1.142	1.150	1.326	1.338	1.461	1.442	1.461	1.477	2.218
Y Mn	0.064	0.059	0.006	0.003	0.026	0.023	0.022	0.024	0.021	0.024	0.037
Y Zn	0.002	0.009	0.003	0.000	0.003	0.011	0.003	0.000	0.004	0.005	0.006
Y Mg	0.437	0.463	1.487	1.473	1.174	1.203	1.193	1.160	0.998	0.985	0.134
Y Li	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
X Ca	0.041	0.040	0.154	0.155	0.040	0.049	0.102	0.101	0.054	0.054	0.042
X Na	0.651	0.609	0.648	0.578	0.597	0.599	0.650	0.609	0.647	0.644	0.553
x K	0.012	0.015	0.015	0.008	0.012	0.009	0.012	0.008	0.006	0.006	0.004
X vac	0.296	0.336	0.183	0.259	0.350	0.343	0.236	0.282	0.293	0.296	0.400
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.029	0.163	0.213	0.140	0.086	0.059	0.087	0.110	0.111	0.063	0.032
W Cl	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
W OH	0.971	0.837	0.639	0.801	0.875	0.941	0.912	0.852	0.644	0.703	0.842
W O	0.000	0.000	0.149	0.059	0.039	0.000	0.000	0.038	0.245	0.234	0.126
Classif.	schorl	schorl	dravite	dravite	schorl	schorl	schorl	schorl	schorl	schorl	schorl

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site	SIMPLE12-S01						SIMPLE12-S01					
Comments	oscillatory center tur: light BSE intermediate	oscillatory center tur: dark BSE rim	oscillatory center tur: dark BSE rim	tur fan base: dark in BSE	tur fan base: dark in BSE	tur fan base: medium gray in BSE	tur fan base: medium gray in BSE	tur fan base: light in BSE	tur fan base: light in BSE	tur fan top: dark in BSE	tur fan top: dark in BSE	tur fan top: light in BSE
Point	93t-4	93t-5	93t-6	94t-1	94t-2	94t-3	94t-4	94t-5	94t-6	95t-1	95t-2	95t-3
SiO ₂ (wt.%)	34.27	36.18	35.97	34.87	34.69	34.05	34.27	35.11	35.15	34.70	34.74	34.09
TiO ₂	0.58	0.54	0.47	0.46	0.45	0.73	0.66	0.22	0.33	0.62	0.50	0.65
B ₂ O ₃ *	10.21	10.55	10.53	10.46	10.48	10.38	10.33	10.45	10.44	10.41	10.44	10.34
Al ₂ O ₃	33.57	32.77	32.73	33.21	33.51	33.16	32.99	35.09	34.96	33.20	33.75	34.49
Cr ₂ O ₃	0.00	0.00	0.00	0.00	0.02	0.03	0.00	0.06	0.00	0.00	0.02	0.00
Bi ₂ O ₃	0.00	0.00	0.00									
Fe ₂ O ₃ *	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.00	0.00	0.00	0.00	0.00
FeO*	15.93	7.34	7.74	8.37	8.29	9.66	9.18	10.53	10.37	9.10	8.97	10.67
FeO (tot)	15.93	7.34	7.74	8.37	8.29	9.90	9.18	10.53	10.37	9.10	8.97	10.67
MnO	0.29	0.04	0.04	0.08	0.06	0.13	0.12	0.12	0.16	0.08	0.10	0.11
ZnO	0.03	0.03	0.00	0.00	0.07	0.08	0.01	0.02	0.03	0.00	0.03	0.07
MgO	0.18	6.49	6.37	5.91	5.97	5.01	5.20	3.10	3.16	5.28	5.10	3.31
Li 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
CaO	0.26	0.36	0.33	0.59	0.76	0.64	0.62	0.23	0.21	0.59	0.54	0.44
Na ₂ O	1.60	2.16	2.13	2.01	1.77	1.83	1.96	1.71	1.55	2.10	1.95	1.83
K ₂ O	0.03	0.02	0.02	0.05	0.06	0.08	0.07	0.06	0.07	0.06	0.05	0.05
F	0.02	0.23	0.14	0.47	0.43	0.22	0.40	0.41	0.16	0.38	0.29	0.21
Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.00	0.00
H ₂ O*	3.36	3.32	3.43	3.31	3.40	3.48	3.27	3.18	3.33	3.25	3.34	3.26
-(O=F,Cl)	-0.01	-0.10	-0.06	-0.20	-0.18	-0.09	-0.17	-0.17	-0.07	-0.16	-0.12	-0.09
Total	100.32	99.94	99.84	99.59	99.78	99.65	98.90	100.11	99.84	99.63	99.69	99.42
T Si (apfu)	5.833	5.959	5.936	5.797	5.751	5.698	5.765	5.837	5.850	5.794	5.782	5.731
T Al	0.167	0.041	0.064	0.203	0.249	0.302	0.235	0.163	0.150	0.206	0.218	0.269
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.074	0.067	0.058	0.058	0.056	0.092	0.083	0.028	0.041	0.078	0.062	0.082
Y Al	0.567	0.319	0.301	0.303	0.299	0.240	0.305	0.714	0.706	0.325	0.402	0.565
Y Cr	0.000	0.000	0.000	0.000	0.003	0.004	0.000	0.008	0.000	0.000	0.003	0.000
Y Fe ³⁺	0.000	0.000	0.000	0.000	0.000	0.034	0.000	0.000	0.000	0.000	0.000	0.000
Y Fe ²⁺	2.268	1.011	1.068	1.164	1.149	1.352	1.291	1.464	1.443	1.270	1.249	1.500
Y Mn	0.042	0.006	0.006	0.011	0.009	0.019	0.017	0.016	0.023	0.011	0.014	0.015
Y Zn	0.004	0.004	0.000	0.000	0.008	0.010	0.001	0.003	0.003	0.000	0.004	0.009
Y Mg	0.046	1.593	1.567	1.464	1.475	1.250	1.304	0.767	0.783	1.315	1.266	0.829
Y Li	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
X Ca	0.047	0.064	0.058	0.105	0.135	0.115	0.111	0.040	0.037	0.105	0.097	0.080
X Na	0.528	0.690	0.681	0.649	0.569	0.594	0.639	0.551	0.500	0.681	0.629	0.595
x K	0.007	0.004	0.004	0.010	0.013	0.016	0.015	0.012	0.015	0.014	0.010	0.010
X vac	0.418	0.243	0.256	0.236	0.283	0.275	0.234	0.397	0.449	0.200	0.264	0.315
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.011	0.120	0.073	0.245	0.226	0.117	0.214	0.213	0.082	0.202	0.151	0.114
W Cl	0.000	0.000	0.000	0.001	0.000	0.000	0.002	0.002	0.000	0.002	0.000	0.001
W OH	0.812	0.647	0.771	0.670	0.755	0.883	0.672	0.527	0.692	0.616	0.706	0.659
W O	0.178	0.233	0.156	0.085	0.018	0.000	0.113	0.257	0.226	0.180	0.143	0.226
Classif.	schorl	dravite	dravite	dravite	dravite	schorl	dravite	schorl	schorl	dravite	dravite	schorl

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site	SIMPLE12-S02		SIMPLE13-S01		SIMPLE13-S01		SIMPLE14-S01		SIMPLE14-S01			
Comments	tur fan top: light in BSE	aplite tur (homogeneous)	aplite tur (homogeneous)	fine tur (homogeneous)	fine tur (homogeneous)	large tur (homogeneous)	large tur (homogeneous)	black tur	black tur	big contact tur: core	big contact tur: core	big contact tur: rim
Point	95t-4	96t-1	96t-2	97t-1	97t-2	98t-1	98t-2	99t-1	99t-2	100t-1	100t-2	100t-3
SiO ₂ (wt.%)	34.52	34.56	34.62	34.15	34.83	33.64	33.74	34.43	34.37	35.24	35.24	34.29
TiO ₂	0.37	0.41	0.41	0.97	0.87	0.44	0.46	0.45	0.47	0.45	0.42	1.03
B ₂ O ₃ *	10.37	10.42	10.40	10.20	10.23	10.10	10.10	10.32	10.33	10.49	10.53	10.35
Al ₂ O ₃	34.38	33.39	33.24	29.32	29.29	32.69	32.68	34.54	34.65	34.34	34.80	33.75
Cr ₂ O ₃	0.00	0.00	0.02	0.01	0.00	0.01	0.05	0.04	0.04	0.01	0.04	0.01
Bi ₂ O ₃												
Fe ₂ O ₃ *	0.00	0.00	0.00	1.87	1.09	0.00	0.07	0.00	0.00	0.00	0.00	0.00
FeO*	10.67	9.30	8.99	11.95	12.53	14.83	14.64	12.75	12.46	7.48	7.59	12.29
FeO (tot)	10.67	9.30	8.99	13.64	13.51	14.83	14.71	12.75	12.46	7.48	7.59	12.29
MnO	0.08	0.10	0.11	0.42	0.46	1.57	1.60	0.16	0.22	0.05	0.02	0.17
ZnO	0.16	0.01	0.04	0.00	0.04	0.13	0.06	0.03	0.00	0.00	0.00	0.03
MgO	3.37	5.28	5.39	4.58	4.42	0.54	0.58	1.86	1.99	5.47	5.29	2.69
Li 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
CaO	0.49	0.67	0.60	0.45	0.45	0.10	0.11	0.32	0.32	0.83	0.74	0.26
Na ₂ O	1.82	1.90	1.89	2.44	2.33	1.94	1.76	1.74	1.71	1.72	1.77	1.81
K ₂ O	0.04	0.07	0.05	0.06	0.06	0.04	0.03	0.05	0.04	0.04	0.03	0.03
F	0.17	0.25	0.38	0.28	0.32	0.18	0.14	0.29	0.06	0.10	0.25	0.35
Cl	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
H ₂ O*	3.28	3.43	3.36	3.39	3.38	3.38	3.42	3.19	3.33	3.24	3.20	3.27
-(O=F,Cl)	-0.07	-0.10	-0.16	-0.12	-0.13	-0.08	-0.06	-0.12	-0.02	-0.05	-0.10	-0.15
Total	99.65	99.68	99.34	99.99	100.18	99.51	99.39	100.05	99.97	99.41	99.80	100.17
T Si (apfu)	5.789	5.763	5.784	5.818	5.915	5.791	5.803	5.796	5.782	5.841	5.819	5.760
T Al	0.211	0.237	0.216	0.182	0.085	0.209	0.197	0.204	0.218	0.159	0.181	0.240
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	5.707	5.778	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.046	0.052	0.051	0.125	0.111	0.057	0.059	0.058	0.060	0.056	0.052	0.130
Y Al	0.583	0.324	0.329	0.000	0.000	0.422	0.429	0.649	0.652	0.549	0.590	0.443
Y Cr	0.000	0.000	0.002	0.002	0.000	0.001	0.007	0.005	0.005	0.001	0.005	0.001
Y Fe ³⁺	0.000	0.000	0.000	0.240	0.139	0.000	0.009	0.000	0.000	0.000	0.000	0.000
Y Fe ²⁺	1.497	1.296	1.256	1.702	1.780	2.135	2.107	1.796	1.753	1.037	1.048	1.726
Y Mn	0.012	0.014	0.016	0.060	0.067	0.229	0.234	0.022	0.032	0.007	0.003	0.024
Y Zn	0.020	0.002	0.005	0.000	0.006	0.017	0.008	0.004	0.000	0.000	0.000	0.003
Y Mg	0.842	1.312	1.341	1.164	1.120	0.139	0.149	0.467	0.498	1.350	1.302	0.673
Y Li	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
X Ca	0.089	0.120	0.107	0.083	0.082	0.019	0.020	0.058	0.057	0.147	0.130	0.047
X Na	0.592	0.614	0.611	0.806	0.768	0.647	0.588	0.569	0.557	0.552	0.566	0.588
x K	0.009	0.014	0.010	0.012	0.013	0.008	0.008	0.010	0.009	0.009	0.007	0.007
X vac	0.310	0.252	0.272	0.099	0.136	0.326	0.385	0.363	0.377	0.292	0.296	0.358
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.092	0.129	0.202	0.150	0.170	0.096	0.076	0.155	0.031	0.054	0.129	0.187
W Cl	0.000	0.000	0.002	0.001	0.000	0.001	0.000	0.000	0.000	0.002	0.000	0.000
W OH	0.664	0.812	0.743	0.850	0.830	0.883	0.924	0.585	0.731	0.586	0.520	0.660
W O	0.244	0.059	0.052	0.000	0.000	0.020	0.000	0.260	0.238	0.358	0.351	0.153
Classif.	schorl	dravite	dravite	schorl	schorl	schorl	schorl	schorl	schorl	dravite	dravite	schorl

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site	SIMPLE14-S01						SIMPLE16-S02				
Comments	big contact tur: rim	small contact tur: core	small contact tur: core	small contact tur: intermediate	small contact tur: intermediate	small contact tur: rim	small contact tur: rim	"green" (practically black) tur: core	"green" (practically black) tur: core	"green" (practically black) tur: intermediate	"green" (practically black) tur: intermediate
Point	100t-4	101t-1	101t-2	101t-3	101t-4	101t-5	101t-6	102t-1	102t-2	102t-3	102t-4
SiO ₂ (wt.%)	34.33	32.44	33.20	31.71	31.91	34.02	33.93	34.50	34.33	34.42	34.97
TiO ₂	0.98	0.43	0.43	0.49	0.53	0.50	0.45	0.49	0.60	0.56	0.48
B ₂ O ₃ *	10.32	9.61	9.62	9.18	9.35	10.12	10.12	10.35	10.40	10.39	10.45
Al ₂ O ₃	34.04	32.78	31.09	30.33	30.98	33.83	33.82	34.54	34.79	34.55	34.35
Cr ₂ O ₃	0.01	0.00	0.01	0.07	0.01	0.00	0.00	0.00	0.04	0.00	0.00
Bi ₂ O ₃											
Fe ₂ O ₃ *	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO*	12.16	6.57	7.81	6.47	6.99	9.73	9.94	9.79	9.71	7.93	8.02
FeO (tot)	12.16	6.57	7.81	6.47	6.99	9.73	9.94	9.79	9.71	7.93	8.02
MnO	0.21	0.06	0.06	0.00	0.01	0.08	0.07	0.04	0.05	0.04	0.03
ZnO	0.03	0.04	0.04	0.00	0.02	0.02	0.08	0.03	0.14	0.03	0.00
MgO	2.34	4.00	4.20	3.88	3.99	3.25	3.19	3.72	3.83	4.96	5.13
Li ₂ O*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CaO	0.24	0.56	0.50	0.47	0.48	0.40	0.45	0.40	0.44	0.65	0.63
Na ₂ O	1.80	1.61	1.68	1.64	1.63	1.77	1.48	1.78	1.95	1.80	1.95
K ₂ O	0.03	0.02	0.03	0.05	0.02	0.04	0.05	0.07	0.05	0.09	0.07
F	0.16	0.24	0.04	0.04	0.31	0.11	0.05	0.29	0.13	0.16	0.21
Cl	0.00	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00
H ₂ O*	3.26	2.68	2.86	2.64	2.60	3.08	3.21	3.19	3.28	3.23	3.19
-(O=F,Cl)	-0.07	-0.10	-0.02	-0.02	-0.13	-0.05	-0.02	-0.12	-0.06	-0.07	-0.09
Total	99.84	90.96	91.57	86.94	88.70	96.93	96.83	99.06	99.70	98.76	99.38
T Si (apfu)	5.782	5.867	5.997	6.000	5.935	5.843	5.829	5.791	5.734	5.760	5.816
T Al	0.218	0.133	0.003	0.000	0.065	0.157	0.171	0.209	0.266	0.240	0.184
B	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.124	0.059	0.058	0.070	0.075	0.065	0.059	0.061	0.076	0.071	0.060
Y Al	0.540	0.855	0.615	0.765	0.725	0.689	0.676	0.625	0.584	0.573	0.549
Y Cr	0.002	0.000	0.001	0.010	0.002	0.000	0.000	0.000	0.006	0.000	0.000
Y Fe ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y Fe ²⁺	1.713	0.994	1.179	1.023	1.087	1.398	1.428	1.375	1.356	1.109	1.116
Y Mn	0.030	0.010	0.008	0.000	0.001	0.012	0.009	0.005	0.007	0.006	0.004
Y Zn	0.004	0.005	0.006	0.000	0.003	0.003	0.010	0.004	0.018	0.004	0.000
Y Mg	0.588	1.078	1.132	1.095	1.106	0.833	0.818	0.930	0.954	1.238	1.271
Y Li	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
X Ca	0.043	0.108	0.096	0.095	0.095	0.074	0.083	0.071	0.078	0.117	0.113
X Na	0.588	0.566	0.589	0.600	0.587	0.591	0.493	0.579	0.631	0.583	0.628
x K	0.006	0.005	0.008	0.012	0.006	0.010	0.011	0.015	0.011	0.019	0.014
X vac	0.363	0.321	0.308	0.293	0.312	0.326	0.412	0.335	0.280	0.281	0.245
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.085	0.137	0.025	0.022	0.181	0.061	0.025	0.153	0.070	0.084	0.109
W Cl	0.000	0.004	0.005	0.001	0.000	0.000	0.001	0.000	0.004	0.002	0.000
W OH	0.663	0.233	0.452	0.336	0.223	0.529	0.680	0.573	0.652	0.605	0.537
W O	0.252	0.627	0.519	0.642	0.596	0.410	0.294	0.274	0.274	0.309	0.354
Classif.	schorl	oxy-FALSE	oxy-FALSE	oxy-FALSE	oxy-FALSE	schorl	schorl	schorl	schorl	dravite	dravite

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site	SIMPLE17-S01						SIMPLE17-S01					
Comments	"green" (practically black) tur: rim	"green" (practically black) tur: rim	long black xtl tur top: dark in BSE	long black xtl tur top: dark in BSE	long black xtl tur top: medium in BSE	long black xtl tur top: medium in BSE	long black xtl tur top: light in BSE	long black xtl tur top: light in BSE	long black xtl tur base: light in BSE	long black xtl tur base: light in BSE	long black xtl tur base: dark in BSE	long black xtl tur base: dark in BSE
Point	102t-5	102t-6	103t-1	103t-2	103t-3	103t-4	103t-5	103t-6	104t-1	104t-2	104t-3	104t-4
SiO ₂ (wt.%)	35.12	34.91	34.61	34.73	34.62	34.52	34.11	33.87	34.22	34.43	35.30	35.09
TiO ₂	0.47	0.52	0.81	0.81	1.12	1.03	0.64	0.61	0.65	0.69	0.88	0.98
B ₂ O ₃ *	10.56	10.51	10.29	10.38	10.28	10.30	10.08	10.10	10.29	10.37	10.47	10.39
Al ₂ O ₃	34.57	34.46	32.93	33.30	31.96	32.12	32.58	32.64	33.55	33.73	30.32	29.89
Cr ₂ O ₃	0.00	0.02	0.02	0.03	0.05	0.01	0.00	0.01	0.00	0.03	0.00	0.00
Bi ₂ O ₃												
Fe ₂ O ₃ *	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO*	5.51	5.70	10.67	11.45	6.35	6.25	10.61	10.78	10.94	11.07	5.21	5.43
FeO (tot)	5.51	5.70	10.67	11.45	6.35	6.25	10.61	10.78	10.94	11.07	5.21	5.43
MnO	0.02	0.00	0.20	0.15	0.09	0.06	0.13	0.17	0.12	0.14	0.02	0.08
ZnO	0.08	0.19	0.00	0.07	0.07	0.00	0.00	0.07	0.11	0.00	0.05	0.04
MgO	6.90	6.64	3.80	3.52	6.76	7.00	3.39	3.44	3.53	3.60	9.55	9.37
Li 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
CaO	1.03	1.06	0.64	0.63	0.84	0.81	0.58	0.66	0.61	0.65	2.42	2.42
Na ₂ O	1.78	1.86	1.78	1.84	1.93	2.02	1.88	1.85	1.84	1.68	1.39	1.27
K ₂ O	0.05	0.07	0.04	0.02	0.05	0.04	0.06	0.07	0.05	0.05	0.02	0.02
F	0.22	0.23	0.16	0.16	0.22	0.37	0.14	0.20	0.29	0.11	0.44	0.39
Cl	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.00	0.00	0.01	0.00
H ₂ O*	3.25	3.18	3.22	3.29	3.15	3.14	3.06	3.11	3.21	3.37	3.23	3.25
-(O=F,Cl)	-0.09	-0.10	-0.07	-0.07	-0.09	-0.16	-0.06	-0.09	-0.12	-0.05	-0.19	-0.16
Total	99.48	99.26	99.11	100.32	97.41	97.52	97.21	97.49	99.29	99.85	99.11	98.46
T Si (apfu)	5.777	5.771	5.846	5.813	5.856	5.826	5.879	5.830	5.778	5.772	5.861	5.870
T Al	0.223	0.229	0.154	0.187	0.144	0.174	0.121	0.170	0.222	0.228	0.139	0.130
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	5.795	5.762
Y Ti	0.058	0.064	0.103	0.102	0.143	0.130	0.083	0.079	0.082	0.087	0.109	0.124
Y Al	0.480	0.485	0.400	0.384	0.227	0.215	0.498	0.452	0.455	0.437	0.000	0.000
Y Cr	0.000	0.003	0.003	0.004	0.007	0.002	0.000	0.001	0.000	0.004	0.000	0.000
Y Fe ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y Fe ²⁺	0.758	0.788	1.507	1.603	0.898	0.882	1.529	1.552	1.545	1.552	0.723	0.760
Y Mn	0.003	0.000	0.029	0.021	0.013	0.009	0.019	0.024	0.017	0.019	0.003	0.012
Y Zn	0.010	0.023	0.000	0.008	0.009	0.000	0.000	0.009	0.013	0.000	0.006	0.005
Y Mg	1.691	1.637	0.957	0.879	1.704	1.762	0.870	0.883	0.888	0.901	2.363	2.338
Y Li	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
X Ca	0.182	0.188	0.116	0.114	0.153	0.146	0.107	0.123	0.110	0.116	0.430	0.434
X Na	0.568	0.595	0.584	0.598	0.632	0.661	0.629	0.619	0.601	0.547	0.448	0.412
x K	0.011	0.015	0.008	0.005	0.011	0.010	0.013	0.015	0.011	0.010	0.005	0.005
X vac	0.239	0.202	0.291	0.283	0.203	0.184	0.251	0.244	0.277	0.327	0.117	0.149
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.116	0.119	0.086	0.086	0.118	0.198	0.077	0.109	0.156	0.060	0.232	0.204
W Cl	0.001	0.000	0.000	0.000	0.002	0.002	0.000	0.003	0.000	0.000	0.001	0.000
W OH	0.567	0.507	0.633	0.679	0.557	0.535	0.524	0.569	0.613	0.764	0.579	0.632
W O	0.316	0.374	0.281	0.235	0.324	0.265	0.399	0.319	0.231	0.176	0.188	0.164
Classif.	dravite	dravite	schorl	schorl	dravite	dravite	schorl	schorl	schorl	schorl	dravite	uvite

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site	SMALL-S01-5		THIN-S01		TOUR-S01		TOUR-S01		TOURMUS-S01			
Comments	black tur	black tur	contact tur (homogeneous)	contact tur (homogeneous)	center black tur (homogeneous)	center black tur (homogeneous)	border tur: core	border tur: core	border tur: rim	border tur: rim	core tur (homogeneous)	core tur (homogeneous)
Point	105t-1	105t-2	106t-1	106t-2	107t-1	107t-2	108t-1	108t-2	108t-3	108t-4	109t-1	109t-2
SiO ₂ (wt.%)	34.49	34.19	33.92	34.38	34.72	34.75	34.42	34.75	34.59	35.04	34.28	34.03
TiO ₂	0.41	0.51	0.72	0.44	0.12	0.13	0.63	0.50	0.78	0.49	0.16	0.16
B ₂ O ₃ *	10.40	10.42	10.29	10.37	10.34	10.34	10.45	10.51	10.34	10.44	10.18	10.19
Al ₂ O ₃	33.46	33.67	31.78	32.73	35.40	35.38	34.74	34.81	33.59	34.31	33.46	33.56
Cr ₂ O ₃	0.00	0.00	0.00	0.00	0.06	0.03	0.03	0.04	0.06	0.02	0.01	0.04
Bi ₂ O ₃												
Fe ₂ O ₃ *	0.00	0.27	0.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO*	8.32	8.18	8.93	9.27	11.35	11.46	6.45	6.83	10.45	7.41	14.25	14.51
FeO (tot)	8.32	8.42	9.71	9.27	11.35	11.46	6.45	6.83	10.45	7.41	14.25	14.51
MnO	0.04	0.08	0.11	0.10	0.12	0.09	0.00	0.00	0.15	0.07	0.82	0.73
ZnO	0.04	0.04	0.00	0.06	0.04	0.00	0.03	0.00	0.03	0.00	0.03	0.16
MgO	5.68	5.72	5.83	5.60	2.06	2.00	5.95	5.89	3.70	5.35	0.91	0.90
Li 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
CaO	0.59	0.65	0.82	0.82	0.07	0.06	1.09	1.41	0.18	0.20	0.06	0.05
Na ₂ O	1.73	1.75	1.89	2.03	1.53	1.45	1.62	1.44	1.92	1.92	1.65	1.75
K ₂ O	0.03	0.07	0.05	0.08	0.02	0.04	0.05	0.06	0.02	0.03	0.05	0.03
F	0.28	0.23	0.19	0.16	0.09	0.00	0.08	0.22	0.62	0.37	0.46	0.12
Cl	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.02	0.00	0.00	0.01	0.00
H ₂ O*	3.45	3.49	3.46	3.44	3.31	3.35	3.25	3.17	3.11	3.23	3.23	3.45
-(O=F,Cl)	-0.12	-0.10	-0.08	-0.07	-0.04	0.00	-0.04	-0.10	-0.26	-0.16	-0.19	-0.05
Total	98.80	99.16	98.78	99.42	99.19	99.09	98.75	99.55	99.27	98.72	99.37	99.63
T Si (apfu)	5.766	5.703	5.728	5.761	5.834	5.843	5.727	5.748	5.816	5.833	5.854	5.805
T Al	0.234	0.297	0.272	0.239	0.166	0.157	0.273	0.252	0.184	0.167	0.146	0.195
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.052	0.064	0.091	0.056	0.015	0.016	0.079	0.062	0.098	0.061	0.021	0.021
Y Al	0.359	0.323	0.054	0.225	0.845	0.854	0.540	0.534	0.472	0.566	0.589	0.550
Y Cr	0.000	0.000	0.000	0.000	0.009	0.004	0.004	0.005	0.008	0.003	0.002	0.005
Y Fe ³⁺	0.000	0.033	0.110	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y Fe ²⁺	1.164	1.141	1.260	1.299	1.595	1.612	0.898	0.945	1.470	1.031	2.034	2.070
Y Mn	0.006	0.011	0.016	0.014	0.016	0.013	0.000	0.000	0.022	0.010	0.118	0.105
Y Zn	0.005	0.005	0.000	0.007	0.005	0.000	0.004	0.000	0.003	0.000	0.004	0.021
Y Mg	1.415	1.423	1.468	1.400	0.515	0.501	1.475	1.453	0.926	1.329	0.232	0.228
Y Li	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
X Ca	0.106	0.116	0.148	0.147	0.013	0.011	0.194	0.250	0.032	0.035	0.011	0.009
X Na	0.559	0.565	0.619	0.660	0.499	0.471	0.523	0.463	0.626	0.619	0.546	0.579
x K	0.005	0.015	0.010	0.018	0.005	0.009	0.010	0.012	0.004	0.006	0.011	0.007
X vac	0.329	0.304	0.223	0.175	0.483	0.508	0.273	0.275	0.338	0.339	0.432	0.405
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.147	0.120	0.101	0.085	0.047	0.000	0.044	0.114	0.328	0.196	0.248	0.065
W Cl	0.000	0.000	0.000	0.002	0.000	0.002	0.000	0.004	0.000	0.000	0.002	0.000
W OH	0.846	0.880	0.899	0.842	0.705	0.761	0.605	0.495	0.485	0.584	0.685	0.929
W O	0.006	0.000	0.000	0.071	0.248	0.237	0.351	0.386	0.187	0.221	0.066	0.006
Classif.	dravite	dravite	dravite	dravite	schorl	foitite	dravite	dravite	schorl	dravite	schorl	schorl

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site	TOURMUS-S01		TOURMUS-S01		TOURMUS-S01							
Comments	contact tur (homogeneous)	contact tur (homogeneous)	tur; 2 faint gradational zones: core	tur; 2 faint gradational zones: core	tur; 2 faint gradational zones: rim	tur; 2 faint gradational zones: rim	black tur next to beryl, gar, and musc: core	black tur next to beryl, gar, and musc: core	black tur next to beryl, gar, and musc: intermediate	black tur next to beryl, gar, and musc: intermediate	black tur next to beryl, gar, and musc: rim	black tur next to beryl, gar, and musc: rim
Point	110t-1	110t-2	111t-1	111t-2	111t-3	111t-4	112t-1	112t-2	112t-3	112t-4	112t-5	112t-6
SiO ₂ (wt.%)	35.36	35.31	34.24	34.26	33.60	33.68	35.23	35.31	34.31	33.75	34.71	34.60
TiO ₂	0.29	0.34	0.22	0.23	0.50	0.51	0.20	0.22	0.53	0.54	0.57	0.51
B ₂ O ₃ *	10.49	10.48	10.32	10.27	10.21	10.23	10.53	10.47	10.38	10.27	10.52	10.54
Al ₂ O ₃	34.06	33.87	33.92	33.47	32.75	32.71	34.50	34.21	34.98	34.83	36.61	36.89
Cr ₂ O ₃	0.02	0.01	0.02	0.00	0.05	0.00	0.00	0.00	0.07	0.03	0.00	0.01
Bi ₂ O ₃												
Fe ₂ O ₃ *	0.00	0.00	0.38	0.56	0.53	0.82	0.14	0.00	0.00	0.00	0.00	0.00
FeO*	7.69	7.77	10.73	10.61	11.98	11.76	8.58	8.74	11.48	11.57	8.25	7.90
FeO (tot)	7.69	7.77	11.07	11.11	12.46	12.49	8.71	8.74	11.48	11.57	8.25	7.90
MnO	0.02	0.04	0.11	0.17	0.21	0.21	0.14	0.05	0.80	0.79	1.43	1.49
ZnO	0.04	0.02	0.06	0.04	0.09	0.02	0.01	0.06	0.04	0.03	0.00	0.02
MgO	5.58	5.67	3.55	3.56	3.26	3.36	4.99	4.82	1.38	1.42	1.26	1.01
Li ₂ O*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.23	0.64	0.77
CaO	0.43	0.43	0.15	0.19	0.26	0.26	0.24	0.25	0.14	0.13	0.18	0.14
Na ₂ O	1.77	1.59	1.75	1.61	2.09	2.01	1.56	1.70	1.91	1.79	1.94	2.34
K ₂ O	0.05	0.04	0.02	0.02	0.05	0.05	0.04	0.03	0.02	0.04	0.03	0.03
F	0.19	0.21	0.09	0.40	0.38	0.10	0.34	0.03	0.67	0.49	0.80	0.97
Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00
H ₂ O*	3.37	3.44	3.52	3.35	3.34	3.48	3.47	3.50	3.27	3.31	3.25	3.18
-(O=F,Cl)	-0.08	-0.09	-0.04	-0.17	-0.16	-0.04	-0.14	-0.02	-0.28	-0.21	-0.34	-0.41
Total	99.28	99.14	99.03	98.61	99.14	99.15	99.83	99.40	100.01	99.03	99.85	100.01
T Si (apfu)	5.859	5.853	5.766	5.796	5.719	5.724	5.815	5.861	5.744	5.712	5.733	5.704
T Al	0.141	0.147	0.234	0.204	0.281	0.276	0.185	0.139	0.256	0.288	0.267	0.296
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.036	0.043	0.027	0.030	0.063	0.066	0.025	0.028	0.067	0.069	0.071	0.063
Y Al	0.510	0.470	0.497	0.470	0.288	0.274	0.526	0.552	0.646	0.658	0.858	0.873
Y Cr	0.003	0.001	0.002	0.000	0.006	0.000	0.000	0.000	0.010	0.004	0.000	0.002
Y Fe ³⁺	0.000	0.000	0.048	0.071	0.068	0.104	0.017	0.000	0.000	0.000	0.000	0.000
Y Fe ²⁺	1.065	1.077	1.511	1.501	1.706	1.671	1.185	1.213	1.606	1.638	1.139	1.089
Y Mn	0.002	0.005	0.015	0.025	0.030	0.030	0.020	0.007	0.114	0.114	0.199	0.208
Y Zn	0.005	0.002	0.007	0.006	0.011	0.003	0.001	0.008	0.005	0.004	0.000	0.003
Y Mg	1.379	1.402	0.891	0.899	0.828	0.851	1.227	1.192	0.345	0.359	0.309	0.249
Y Li	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.208	0.154	0.423	0.513
X Ca	0.076	0.077	0.028	0.035	0.047	0.046	0.043	0.044	0.025	0.024	0.032	0.026
X Na	0.569	0.512	0.572	0.529	0.689	0.662	0.500	0.549	0.621	0.587	0.620	0.749
x K	0.010	0.009	0.004	0.005	0.010	0.011	0.008	0.007	0.004	0.008	0.007	0.007
X vac	0.345	0.402	0.396	0.431	0.254	0.281	0.449	0.400	0.350	0.381	0.341	0.219
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.100	0.108	0.049	0.215	0.203	0.056	0.175	0.017	0.352	0.262	0.416	0.505
W Cl	0.000	0.000	0.000	0.001	0.000	0.000	0.001	0.001	0.000	0.002	0.001	0.000
W OH	0.725	0.807	0.951	0.785	0.797	0.944	0.824	0.870	0.648	0.736	0.583	0.495
W O	0.174	0.085	0.000	0.000	0.000	0.000	0.000	0.111	0.000	0.000	0.000	0.000
Classif.	dravite	dravite	schorl	schorl	schorl	schorl	dravite	schorl	schorl	schorl	schorl	fluor-schorl

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site	WOBBLE-S02				WOBBLE-S02		ZONED-S01	ZONED-S02	CORD-S02-02			
Comments	center tur; 2 faint zones with tiny dissolution features: core	center tur; 2 faint zones with tiny dissolution features: core	center tur; 2 faint zones with tiny dissolution features: rim	center tur; 2 faint zones with tiny dissolution features: rim	border tur (homogeneous)	border tur (homogeneous)	border tur (homogeneous)	border tur (homogeneous)	tur next to ksp & bt (core); homogeneous	tur next to ksp & bt (core); homogeneous	white rim around blue tur, core zone	white rim around blue tur, core zone
Point	113t-1	113t-2	113t-3	113t-4	114t-1	114t-2	115t-1	115t-2	116t-1	116t-2	cdt-1	cdt-2
SiO ₂ (wt.%)	34.60	34.76	34.37	34.17	34.36	34.38	35.08	35.77	34.80	34.69	35.39	35.97
TiO ₂	0.40	0.46	0.86	0.86	0.73	0.73	0.75	0.79	0.69	0.65	0.00	0.04
B ₂ O ₃ *	10.40	10.44	10.39	10.37	10.48	10.47	10.38	10.50	10.43	10.44	10.61	10.62
Al ₂ O ₃	35.64	35.79	34.82	34.54	34.81	34.93	30.86	30.92	33.16	33.14	34.87	34.26
Cr ₂ O ₃	0.01	0.02	0.03	0.02	0.01	0.04	0.02	0.00	0.00	0.01	0.00	0.00
Bi ₂ O ₃												
Fe ₂ O ₃ *	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO*	9.10	8.96	9.50	9.72	6.43	6.12	8.13	8.25	8.89	8.95	7.97	7.01
FeO (tot)	9.10	8.96	9.50	9.72	6.43	6.12	8.13	8.25	8.89	8.95	7.97	7.01
MnO	0.06	0.08	0.07	0.12	0.03	0.05	0.14	0.16	0.13	0.08	0.13	0.12
ZnO	0.08	0.11	0.00	0.09	0.04	0.01	0.00	0.00	0.03	0.05	0.09	0.09
MgO	3.46	3.48	3.76	3.80	6.11	6.10	7.13	7.23	5.40	5.52	5.15	5.65
Li ₂ O*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.21
CaO	0.13	0.15	0.28	0.30	0.91	0.95	0.82	0.79	0.54	0.57	0.34	0.40
Na ₂ O	1.52	1.37	1.77	1.76	1.82	1.67	2.18	2.14	1.93	1.88	1.96	1.92
K ₂ O	0.05	0.03	0.03	0.03	0.04	0.06	0.04	0.06	0.06	0.06	0.03	0.03
F	0.13	0.17	0.21	0.06	0.00	0.14	0.28	0.19	0.11	0.16	0.10	0.13
Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00
H ₂ O*	3.32	3.33	3.25	3.38	3.35	3.26	3.41	3.48	3.44	3.48	3.61	3.60
-(O=F,Cl)	-0.05	-0.07	-0.09	-0.03	0.00	-0.06	-0.12	-0.08	-0.05	-0.07	-0.04	-0.06
Total	98.85	99.08	99.26	99.20	99.12	98.86	99.12	100.22	99.56	99.61	100.35	100.02
T Si (apfu)	5.780	5.785	5.747	5.728	5.696	5.706	5.874	5.921	5.800	5.778	5.800	5.885
T Al	0.220	0.215	0.253	0.272	0.304	0.294	0.126	0.079	0.200	0.222	0.200	0.115
B	3	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	5.964	5.953	6.000	6.000	6.000	6.000
Y Ti	0.050	0.058	0.108	0.109	0.091	0.091	0.095	0.099	0.086	0.082	0.000	0.005
Y Al	0.796	0.806	0.612	0.550	0.497	0.538	0.000	0.000	0.312	0.282	0.535	0.489
Y Cr	0.002	0.002	0.004	0.003	0.001	0.006	0.002	0.000	0.000	0.001	0.000	0.000
Y Fe ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y Fe ²⁺	1.271	1.247	1.329	1.362	0.892	0.849	1.139	1.141	1.239	1.247	1.092	0.959
Y Mn	0.008	0.011	0.010	0.016	0.004	0.007	0.020	0.022	0.019	0.011	0.019	0.016
Y Zn	0.010	0.014	0.000	0.011	0.005	0.001	0.000	0.000	0.004	0.006	0.011	0.011
Y Mg	0.863	0.862	0.938	0.948	1.510	1.509	1.780	1.785	1.340	1.371	1.258	1.379
Y Li	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.085	0.141
X Ca	0.024	0.027	0.050	0.054	0.161	0.168	0.147	0.140	0.096	0.101	0.060	0.071
X Na	0.494	0.443	0.574	0.572	0.585	0.538	0.709	0.688	0.623	0.607	0.622	0.608
x K	0.010	0.007	0.006	0.005	0.009	0.013	0.009	0.013	0.013	0.013	0.007	0.007
X vac	0.473	0.523	0.370	0.369	0.246	0.281	0.135	0.160	0.269	0.279	0.310	0.314
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.068	0.092	0.111	0.033	0.000	0.075	0.149	0.102	0.060	0.082	0.053	0.068
W Cl	0.000	0.000	0.001	0.001	0.000	0.001	0.002	0.002	0.002	0.000	0.000	0.001
W OH	0.704	0.695	0.630	0.783	0.709	0.605	0.808	0.845	0.828	0.870	0.947	0.931
W O	0.229	0.213	0.258	0.183	0.291	0.319	0.042	0.052	0.111	0.048	0.000	0.000
Classif.	schorl	foitite	schorl	schorl	dravite	dravite	dravite	dravite	dravite	dravite	dravite	dravite

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site	JAN-01-01										
Comments	white rim around blue tur, core zone	white rim around blue tur, core zone	white rim around blue tur, core zone	blue tur core; core zone	blue tur rim; core zone	pale blue tur core; core zone	yellow-brown core in blue tur; core zone	grey-brown tur middle; core zone	blue tur rim; core zone	wall zone, white core in zoned white-blue tur	wall zone, white core in zoned white-blue tur
Point	cdt-3	cdt-4	cdt-5	cdt-6	cdt-7	cdt-8	cdt-9	cdt-10	cdt-11	jnt-1	jnt-2
SiO ₂ (wt.%)	35.96	35.66	35.94	35.02	36.68	35.38	35.05	36.14	35.79	35.11	35.44
TiO ₂	0.06	0.01	0.00	0.06	0.07	0.08	0.72	0.11	0.03	0.16	0.07
B ₂ O ₃ *	10.65	10.55	10.61	10.49	10.72	10.64	10.51	10.74	10.66	10.62	10.71
Al ₂ O ₃	34.41	34.47	34.55	34.38	34.37	35.00	33.34	34.32	35.16	36.77	37.59
Cr ₂ O ₃	0.00	0.00	0.03	0.02	0.00	0.03	0.00	0.06	0.00	0.01	0.00
Bi ₂ O ₃											
Fe ₂ O ₃ *	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO*	6.53	7.50	7.26	7.57	6.13	6.01	7.09	5.80	5.41	7.98	7.40
FeO (tot)	6.53	7.50	7.26	7.57	6.13	6.01	7.09	5.80	5.41	7.98	7.40
MnO	0.15	0.11	0.14	0.10	0.11	0.17	0.07	0.04	0.08	1.36	1.40
ZnO	0.02	0.11	0.02	0.04	0.03	0.00	0.05	0.02	0.00	0.05	0.00
MgO	5.98	5.13	5.29	5.36	6.21	6.09	5.95	6.82	6.24	2.78	2.56
Li ₂ O*	0.21	0.16	0.19	0.12	0.20	0.21	0.24	0.23	0.22	0.25	0.36
CaO	0.38	0.30	0.31	0.40	0.17	0.64	1.02	0.87	0.56	0.11	0.14
Na ₂ O	2.00	1.69	1.78	1.84	1.89	1.84	1.65	1.80	1.62	1.53	1.48
K ₂ O	0.01	0.03	0.03	0.02	0.03	0.03	0.03	0.03	0.04	0.04	0.03
F	0.10	0.18	0.14	0.12	0.09	0.12	0.18	0.26	0.17	0.11	0.11
Cl	0.01	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.01	0.00
H ₂ O*	3.63	3.56	3.59	3.56	3.65	3.61	3.54	3.58	3.60	3.61	3.64
-(O=F,Cl)	-0.04	-0.07	-0.06	-0.05	-0.04	-0.05	-0.08	-0.11	-0.07	-0.05	-0.04
Total	100.06	99.38	99.83	99.04	100.33	99.80	99.37	100.70	99.51	100.46	100.88
T Si (apfu)	5.867	5.877	5.887	5.804	5.945	5.781	5.794	5.848	5.833	5.749	5.752
T Al	0.133	0.123	0.113	0.196	0.055	0.219	0.206	0.152	0.167	0.251	0.248
B	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.008	0.001	0.000	0.008	0.008	0.010	0.090	0.013	0.004	0.020	0.009
Y Al	0.485	0.571	0.559	0.520	0.511	0.521	0.289	0.394	0.587	0.845	0.943
Y Cr	0.000	0.000	0.003	0.002	0.000	0.004	0.001	0.008	0.000	0.001	0.000
Y Fe ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y Fe ²⁺	0.892	1.034	0.995	1.049	0.831	0.821	0.980	0.785	0.738	1.093	1.005
Y Mn	0.020	0.015	0.020	0.014	0.015	0.023	0.010	0.006	0.012	0.188	0.192
Y Zn	0.002	0.014	0.002	0.005	0.004	0.000	0.006	0.002	0.000	0.006	0.000
Y Mg	1.456	1.261	1.293	1.324	1.500	1.483	1.466	1.644	1.517	0.680	0.620
Y Li	0.137	0.104	0.128	0.079	0.132	0.138	0.159	0.148	0.142	0.167	0.232
X Ca	0.066	0.053	0.054	0.070	0.030	0.112	0.180	0.151	0.097	0.019	0.024
X Na	0.634	0.540	0.565	0.591	0.594	0.581	0.530	0.564	0.511	0.486	0.464
x K	0.002	0.007	0.006	0.005	0.006	0.006	0.007	0.006	0.008	0.009	0.006
X vac	0.298	0.400	0.375	0.334	0.370	0.300	0.283	0.279	0.383	0.487	0.505
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.052	0.092	0.073	0.064	0.049	0.061	0.095	0.135	0.089	0.058	0.054
W Cl	0.002	0.000	0.002	0.000	0.003	0.003	0.000	0.001	0.000	0.002	0.000
W OH	0.946	0.908	0.925	0.936	0.948	0.936	0.905	0.865	0.911	0.940	0.946
W O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Classif.	dravite	dravite	dravite	dravite	dravite	dravite	dravite	dravite	dravite	schorl	foitite

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site											
Comments	wall zone, white core in zoned white-blue tur	wall zone, dark blue middle in zoned white-blue tur	wall zone, dark blue middle in zoned white-blue tur	wall zone, dark blue rim in zoned white-blue tur	wall zone, white outer rim after dark blue in zoned white-blue tur	border zone; fibrous green radial tur, base	border zone; fibrous green radial tur, top	wall zone; blue-white-blue zoned tur, dark blue core	wall zone; blue-white-blue zoned tur, dark blue core	wall zone; blue-white-blue zoned tur, greenish-white middle	wall zone; blue-white-blue zoned tur, greenish-white middle
Point	jnt-3	jnt-4	jnt-5	jnt-6	jnt-7	jnt-8	jnt-9	jnt-10	jnt-11	jnt-12	jnt-13
SiO ₂ (wt.%)	35.55	34.63	34.67	34.88	34.42	32.71	33.32	34.71	34.55	34.75	34.12
TiO ₂	0.15	0.18	0.19	0.15	0.14	0.58	0.40	0.13	0.05	0.11	0.28
B ₂ O ₃ *	10.65	10.28	10.22	10.21	10.27	10.27	10.31	10.37	10.39	10.70	10.55
Al ₂ O ₃	36.79	32.05	31.47	30.90	33.27	34.71	34.62	34.74	35.08	37.74	37.03
Cr ₂ O ₃	0.00	0.00	0.00	0.00	0.00	0.03	0.04	0.00	0.00	0.05	0.02
Bi ₂ O ₃											
Fe ₂ O ₃ *	0.00	0.90	0.77	0.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO*	7.39	13.07	13.30	13.42	11.35	9.80	10.37	11.41	11.36	7.11	7.88
FeO (tot)	7.39	13.88	13.99	14.09	11.35	9.80	10.37	11.41	11.36	7.11	7.88
MnO	1.45	0.27	0.36	0.32	0.11	0.57	0.48	0.58	0.64	1.24	1.31
ZnO	0.01	0.07	0.07	0.08	0.00	0.00	0.01	0.04	0.00	0.08	0.00
MgO	2.58	2.90	2.82	3.08	3.58	3.97	3.67	2.05	2.13	2.94	2.72
Li ₂ O*	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.12	0.37	0.33
CaO	0.08	0.28	0.20	0.26	0.51	1.07	0.90	0.22	0.18	0.36	0.47
Na ₂ O	1.65	1.94	2.01	2.06	1.96	1.82	1.88	1.54	1.58	1.77	1.72
K ₂ O	0.05	0.05	0.06	0.06	0.07	0.05	0.07	0.04	0.03	0.04	0.02
F	0.05	0.00	0.18	0.06	0.24	0.06	0.01	0.12	0.05	0.15	0.14
Cl	0.00	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.01	0.00
H ₂ O*	3.65	3.55	3.44	3.49	3.28	3.40	3.41	3.52	3.56	3.62	3.57
-(O=F,Cl)	-0.02	0.00	-0.07	-0.03	-0.10	-0.03	0.00	-0.05	-0.02	-0.06	-0.06
Total	100.44	100.17	99.68	99.70	99.13	99.02	99.47	99.58	99.70	100.97	100.11
T Si (apfu)	5.800	5.853	5.898	5.938	5.824	5.533	5.616	5.816	5.782	5.647	5.620
T Al	0.200	0.147	0.102	0.062	0.176	0.467	0.384	0.184	0.218	0.353	0.380
B	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Y Ti	0.018	0.023	0.024	0.019	0.018	0.074	0.051	0.016	0.006	0.014	0.035
Y Al	0.875	0.238	0.208	0.138	0.457	0.454	0.492	0.675	0.702	0.874	0.808
Y Cr	0.000	0.000	0.000	0.000	0.000	0.004	0.005	0.000	0.000	0.007	0.003
Y Fe ³⁺	0.000	0.114	0.098	0.096	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y Fe ²⁺	1.009	1.848	1.892	1.910	1.606	1.386	1.462	1.599	1.590	0.966	1.085
Y Mn	0.200	0.038	0.052	0.046	0.016	0.082	0.068	0.082	0.090	0.171	0.183
Y Zn	0.001	0.009	0.009	0.010	0.000	0.000	0.001	0.005	0.000	0.010	0.000
Y Mg	0.627	0.731	0.716	0.780	0.903	1.000	0.921	0.512	0.532	0.713	0.667
Y Li	0.270	0.000	0.000	0.000	0.000	0.000	0.000	0.112	0.079	0.245	0.219
X Ca	0.014	0.051	0.036	0.048	0.093	0.194	0.162	0.039	0.032	0.062	0.083
X Na	0.521	0.637	0.662	0.681	0.644	0.598	0.614	0.501	0.512	0.557	0.548
x K	0.009	0.010	0.013	0.013	0.016	0.010	0.015	0.010	0.007	0.008	0.005
X vac	0.455	0.302	0.289	0.258	0.247	0.198	0.209	0.451	0.449	0.373	0.364
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.025	0.000	0.095	0.034	0.129	0.030	0.003	0.065	0.026	0.075	0.075
W Cl	0.001	0.003	0.000	0.000	0.003	0.003	0.000	0.000	0.001	0.002	0.000
W OH	0.974	0.997	0.905	0.966	0.705	0.832	0.829	0.935	0.973	0.923	0.925
W O	0.000	0.000	0.000	0.000	0.162	0.135	0.168	0.000	0.000	0.000	0.000
Classif.	schorl	schorl	schorl	schorl	schorl	schorl	schorl	schorl	schorl	schorl	schorl

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site											
Comments	wall zone; blue-white-blue zoned tur, dark blue rim	wall zone; blue-white-blue zoned tur, dark blue rim	centre zone, zoned blue-dark blue-green- dark green tur; blue core	centre zone, zoned blue-dark blue-green- dark green tur; dark blue outer core	centre zone, zoned blue-dark blue-green- dark green tur; yellowish-green middle	centre zone, zoned blue-dark blue-green- dark green tur; yellowish-green middle	centre zone, zoned blue-dark blue-green- dark green tur; dark green rim	centre zone, zoned blue-dark blue-green- dark green tur; dark green rim	centre zone, zoned blue-dark blue-green- dark green tur; yellowish-green middle	centre zone, homogeneous brown long prismatic tur (ident. to blue cores)	centre zone, homogeneous brown long prismatic tur (ident. to blue cores)
Point	jnt-14	jnt-15	jnt-16	jnt-17	jnt-18	jnt-19	jnt-20	jnt-21	jnt-22	jnt-23	jnt-24
SiO ₂ (wt.%)	34.48	34.33	35.12	34.08	34.91	35.74	35.06	35.17	35.79	33.80	33.83
TiO ₂	0.27	0.23	0.16	0.42	0.96	1.06	0.93	1.02	0.95	0.31	0.16
B ₂ O ₃ *	10.33	10.29	10.36	10.20	10.44	10.53	10.36	10.40	10.59	10.18	10.20
Al ₂ O ₃	33.46	32.88	32.64	32.36	31.35	31.25	29.31	29.78	31.84	32.49	32.65
Cr ₂ O ₃	0.07	0.03	0.01	0.05	0.01	0.00	0.04	0.00	0.00	0.03	0.05
Bi ₂ O ₃											
Fe ₂ O ₃ *	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48
FeO*	11.65	12.18	12.22	13.38	6.33	5.66	8.54	7.96	5.61	12.81	12.22
FeO (tot)	11.65	12.18	12.49	13.38	6.33	5.66	8.54	7.96	5.61	12.81	12.65
MnO	0.10	0.10	0.15	0.16	0.10	0.02	0.00	0.04	0.02	0.14	0.10
ZnO	0.06	0.05	0.07	0.09	0.01	0.00	0.04	0.03	0.00	0.07	0.00
MgO	3.43	3.50	3.39	2.71	8.15	8.56	8.00	8.03	8.48	3.10	3.29
Li ₂ O*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CaO	0.54	0.62	0.26	0.44	1.51	1.46	2.18	2.01	1.42	0.48	0.41
Na ₂ O	1.80	1.98	1.76	2.02	1.72	1.78	1.36	1.59	1.60	1.96	1.96
K ₂ O	0.04	0.05	0.06	0.08	0.06	0.04	0.09	0.07	0.05	0.05	0.05
F	0.11	0.01	0.09	0.27	0.31	0.17	0.14	0.25	0.20	0.22	0.08
Cl	0.00	0.02	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.01
H ₂ O*	3.42	3.46	3.53	3.32	3.35	3.34	3.47	3.35	3.41	3.41	3.48
-(O=F,Cl)	-0.04	-0.01	-0.04	-0.12	-0.13	-0.07	-0.06	-0.10	-0.09	-0.09	-0.04
Total	99.71	99.72	100.09	99.47	99.08	99.53	99.46	99.60	99.89	98.98	98.95
T Si (apfu)	5.802	5.799	5.893	5.809	5.810	5.899	5.881	5.880	5.875	5.771	5.763
T Al	0.198	0.201	0.107	0.191	0.190	0.101	0.119	0.120	0.125	0.229	0.237
B	3	3	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	5.961	5.978	5.675	5.747	6.000	6.000	6.000
Y Ti	0.034	0.029	0.020	0.054	0.121	0.132	0.117	0.128	0.118	0.040	0.020
Y Al	0.436	0.344	0.347	0.309	0.000	0.000	0.000	0.000	0.034	0.309	0.319
Y Cr	0.009	0.004	0.001	0.007	0.001	0.000	0.005	0.001	0.000	0.004	0.007
Y Fe ³⁺	0.000	0.000	0.038	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.062
Y Fe ²⁺	1.639	1.721	1.715	1.908	0.881	0.782	1.198	1.113	0.770	1.830	1.740
Y Mn	0.014	0.014	0.021	0.023	0.014	0.002	0.000	0.005	0.003	0.021	0.015
Y Zn	0.008	0.007	0.009	0.011	0.001	0.000	0.005	0.004	0.000	0.009	0.000
Y Mg	0.861	0.882	0.849	0.688	2.022	2.106	2.001	2.002	2.075	0.788	0.836
Y Li	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
X Ca	0.098	0.112	0.048	0.081	0.269	0.257	0.392	0.360	0.250	0.088	0.074
X Na	0.588	0.648	0.574	0.668	0.556	0.570	0.443	0.515	0.510	0.650	0.649
x K	0.008	0.011	0.012	0.018	0.012	0.008	0.019	0.015	0.011	0.011	0.011
X vac	0.306	0.229	0.366	0.233	0.163	0.164	0.146	0.110	0.229	0.251	0.266
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.056	0.008	0.049	0.148	0.163	0.091	0.073	0.130	0.104	0.118	0.042
W Cl	0.001	0.005	0.000	0.001	0.000	0.002	0.001	0.001	0.001	0.002	0.003
W OH	0.837	0.900	0.951	0.770	0.718	0.672	0.886	0.737	0.730	0.879	0.955
W O	0.106	0.087	0.000	0.081	0.119	0.235	0.039	0.133	0.165	0.001	0.000
Classif.	schorl	schorl	schorl	schorl	dravite	dravite	dravite	dravite	dravite	schorl	schorl

Appendix D.1 (contd.): Electron-microprobe analyses of tourmaline.

Site									
Comments	centre zone, homogeneous brown long prismatic tur (ident. to blue cores)	centre zone, homogeneous brown long prismatic tur (ident. to blue cores)	centre zone, zoned blue-dark blue-green-dark green tur; dark blue core	centre zone, zoned blue-dark blue-green-dark green tur; dark blue core	centre zone, zoned blue-dark blue-green-dark green tur; blue outer core	centre zone, zoned blue-dark blue-green-dark green tur; blue outer core	centre zone, zoned blue-dark blue-green-dark green tur; green middle	centre zone, zoned blue-dark blue-green-dark green tur; dark green rim	centre zone, zoned blue-dark blue-green-dark green tur; green middle
Point	jnt-25	jnt-26	jnt-27	jnt-28	jnt-29	jnt-30	jnt-31	jnt-32	jnt-33
SiO ₂ (wt.%)	33.62	34.25	33.81	34.27	33.77	33.52	35.04	34.89	35.27
TiO ₂	0.33	0.21	0.38	0.44	0.69	0.68	0.71	1.06	0.92
B ₂ O ₃ *	10.20	10.33	10.23	10.28	10.15	10.07	10.45	10.37	10.54
Al ₂ O ₃	32.53	33.07	32.34	32.84	32.48	32.26	32.23	29.97	32.33
Cr ₂ O ₃	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bi ₂ O ₃									
Fe ₂ O ₃ *	0.60	0.67	0.69	0.00	0.00	0.00	0.00	0.00	0.00
FeO*	12.61	11.95	12.86	12.72	14.68	14.47	6.46	8.27	4.81
FeO (tot)	13.15	12.56	13.48	12.72	14.68	14.47	6.46	8.27	4.81
MnO	0.16	0.12	0.14	0.29	0.56	0.55	0.00	0.03	0.03
ZnO	0.10	0.12	0.07	0.15	0.09	0.05	0.01	0.00	0.00
MgO	3.08	3.43	3.09	2.94	1.45	1.51	7.51	7.73	8.61
Li ₂ O*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CaO	0.48	0.48	0.45	0.40	0.25	0.27	0.82	2.00	1.00
Na ₂ O	1.99	1.85	2.02	1.93	1.95	2.08	2.04	1.55	2.27
K ₂ O	0.05	0.05	0.07	0.05	0.05	0.07	0.07	0.09	0.05
F	0.08	0.19	0.14	0.05	0.18	0.22	0.10	0.20	0.13
Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
H ₂ O*	3.48	3.47	3.46	3.48	3.36	3.27	3.45	3.37	3.35
-(O=F,Cl)	-0.03	-0.08	-0.06	-0.02	-0.07	-0.09	-0.04	-0.08	-0.06
Total	99.28	100.10	99.70	99.83	99.60	98.92	98.84	99.43	99.26
T Si (apfu)	5.730	5.762	5.746	5.797	5.786	5.785	5.829	5.849	5.818
T Al	0.270	0.238	0.254	0.203	0.214	0.215	0.171	0.151	0.182
B	3	3	3	3	3	3	3	3	3
Z Al	6.000	6.000	6.000	6.000	6.000	6.000	6.000	5.772	6.000
Y Ti	0.042	0.026	0.048	0.056	0.088	0.089	0.088	0.133	0.114
Y Al	0.264	0.316	0.223	0.343	0.344	0.346	0.149	0.000	0.102
Y Cr	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y Fe ³⁺	0.077	0.085	0.088	0.000	0.000	0.000	0.000	0.000	0.000
Y Fe ²⁺	1.797	1.682	1.827	1.799	2.104	2.089	0.898	1.160	0.663
Y Mn	0.023	0.017	0.021	0.041	0.082	0.080	0.000	0.004	0.004
Y Zn	0.012	0.014	0.009	0.019	0.012	0.007	0.001	0.000	0.000
Y Mg	0.784	0.860	0.784	0.742	0.370	0.389	1.862	1.931	2.117
Y Li	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
X Ca	0.088	0.086	0.083	0.073	0.047	0.049	0.147	0.359	0.177
X Na	0.657	0.602	0.665	0.632	0.646	0.696	0.658	0.505	0.727
x K	0.011	0.011	0.015	0.011	0.012	0.014	0.014	0.019	0.010
X vac	0.244	0.301	0.237	0.284	0.295	0.240	0.182	0.117	0.085
V OH	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
V O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W F	0.042	0.102	0.076	0.028	0.096	0.122	0.052	0.104	0.068
W Cl	0.001	0.000	0.000	0.001	0.001	0.000	0.000	0.001	0.002
W OH	0.957	0.898	0.924	0.930	0.845	0.762	0.828	0.765	0.690
W O	0.000	0.000	0.000	0.041	0.059	0.117	0.120	0.130	0.239
Classif.	schorl	schorl	schorl	schorl	schorl	schorl	dravite	dravite	dravite

Appendix D.2: Electron microprobe analyses of K-feldspar.

Site	12-PEGMA-S01	12-PEGMA-S01	12-PEGMA-S01	12-PEGMA-S01	12-PEGMA-S02	12-PEGMA-S02	12-LONG-S01	12-LONG-S01	12-GRANITE-S01	12-GRANITE-S01
Comment	core perthite	core perthite	border albite with ksp inclusions	border albite with ksp inclusions	core perthite	core perthite	porous ksp	porous ksp	core perthite	core perthite
Point	1f-1	1f-2	2f-1	2f-2	6f-1	6f-2	8f-1	8f-2	10f-1	10f-2
P ₂ O ₅ (wt.%)	0.18	0.16	0.09	0.09	0.17	0.21	0.00	0.00	0.06	0.07
SiO ₂	63.47	63.89	63.74	63.55	63.05	62.76	64.06	64.05	64.10	63.46
TiO ₂	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Al ₂ O ₃	18.69	18.68	18.41	18.55	18.36	18.42	18.45	18.42	18.66	18.62
MgO	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00
MnO	0.00	0.01	0.02	0.01	0.02	0.03	0.01	0.00	0.00	0.02
FeO	0.01	0.00	0.00	0.02	0.03	0.00	0.02	0.05	0.01	0.02
ZnO	0.06	0.03	0.02	0.03	0.00	0.05	0.00	0.02	0.02	0.00
BaO	0.07	0.00	0.04	0.11	0.00	0.00	0.01	0.23	0.27	0.14
PbO	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.01
CaO	0.04	0.05	0.03	0.03	0.03	0.00	0.00	0.00	0.09	0.09
Na ₂ O	0.84	0.96	0.64	0.75	1.02	0.75	0.87	0.81	1.36	1.20
K ₂ O	15.79	15.65	16.01	15.91	15.41	16.00	15.69	15.81	14.79	15.14
Rb ₂ O	0.77	0.78	0.79	0.74	0.81	0.85	0.78	0.81	0.78	0.78
Cs ₂ O	0.03	0.02	0.02	0.00	0.03	0.01	0.02	0.03	0.03	0.02
Total	99.98	100.23	99.82	99.80	98.93	99.08	99.91	100.27	100.17	99.60
P (apfu)	0.007	0.006	0.004	0.004	0.007	0.008	0.000	0.000	0.002	0.003
Si	2.958	2.965	2.975	2.967	2.966	2.957	2.982	2.980	2.972	2.964
Ti	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
Al	1.027	1.022	1.013	1.021	1.018	1.023	1.012	1.010	1.020	1.025
Mg	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.001	0.000	0.000
Mn ²⁺	0.000	0.000	0.001	0.000	0.001	0.001	0.000	0.000	0.000	0.001
Fe ²⁺	0.000	0.000	0.000	0.001	0.001	0.000	0.001	0.002	0.000	0.001
Zn	0.002	0.001	0.001	0.001	0.000	0.002	0.000	0.001	0.001	0.000
Ba	0.001	0.000	0.001	0.002	0.000	0.000	0.000	0.004	0.005	0.003
Pb ²⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ca	0.002	0.002	0.002	0.002	0.002	0.000	0.000	0.000	0.004	0.005
Na	0.076	0.086	0.058	0.068	0.093	0.069	0.079	0.073	0.122	0.109
K	0.939	0.926	0.953	0.948	0.925	0.962	0.932	0.938	0.875	0.902
Rb	0.023	0.023	0.024	0.022	0.024	0.026	0.023	0.024	0.023	0.023
Cs	0.001	0.000	0.000	0.000	0.001	0.000	0.000	0.001	0.001	0.000
O	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000

Note: formula recalculated on the basis of 8 anions.

Appendix D.2 (contd.): Electron microprobe analyses of K-feldspar.

Site	12-GRANITE-S04	12-GRANITE-S04	12-GRANITE-S05	12-GRANITE-S05	12-GRANITE-S09	12-GRANITE-S09	12-BERYL-S02	12-BERYL-S02	12-BERYL-S03E	12-BERYL-S03E
Comment	ksp	ksp	perthite	perthite	perthite with graphic growth qtz	perthite with graphic growth qtz	albite with ksp inclusions	albite with ksp inclusions	albite with ksp inclusions	albite with ksp inclusions
Point	13f-1	13f-2	17f-1	17f-2	21f-1	21f-2	117f-1	117f-2	120f-1	120f-2
P ₂ O ₅ (wt.%)	0.16	0.15	0.16	0.15	0.16	0.17	0.08	0.09	0.34	0.49
SiO ₂	63.63	63.47	63.85	64.10	63.87	63.68	64.04	64.15	63.34	63.25
TiO ₂	0.00	0.02	0.00	0.01	0.00	0.00	0.02	0.01	0.00	0.01
Al ₂ O ₃	18.77	18.80	18.76	18.70	18.76	18.70	18.57	18.53	18.77	19.13
MgO	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	0.00	0.00	0.02	0.02	0.00	0.00	0.01	0.00	0.02	0.00
FeO	0.03	0.01	0.04	0.01	0.00	0.01	0.01	0.00	0.02	0.01
ZnO	0.00	0.00	0.01	0.00	0.00	0.03	0.06	0.00	0.00	0.00
BaO	0.07	0.00	0.09	0.04	0.15	0.10	0.09	0.00	0.00	0.12
PbO	0.01	0.00	0.02	0.00	0.00	0.05	0.00	0.02	0.00	0.00
CaO	0.03	0.02	0.03	0.03	0.01	0.02	0.00	0.00	0.00	0.00
Na ₂ O	1.31	1.02	1.18	1.27	1.16	1.16	0.88	0.83	0.73	0.61
K ₂ O	15.02	15.56	15.27	15.11	15.31	15.26	15.68	15.84	15.80	16.05
Rb ₂ O	0.78	0.76	0.76	0.75	0.75	0.75	0.86	0.84	0.82	0.79
Cs ₂ O	0.03	0.02	0.00	0.02	0.00	0.01	0.09	0.06	0.06	0.05
Total	99.84	99.84	100.20	100.21	100.17	99.94	100.39	100.37	99.90	100.51
P (apfu)	0.006	0.006	0.006	0.006	0.006	0.007	0.003	0.004	0.013	0.019
Si	2.960	2.957	2.962	2.968	2.963	2.962	2.972	2.976	2.952	2.933
Ti	0.000	0.001	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000
Al	1.029	1.032	1.026	1.020	1.026	1.025	1.016	1.013	1.031	1.045
Mg	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mn ²⁺	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.001	0.000
Fe ²⁺	0.001	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.001	0.000
Zn	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.000	0.000	0.000
Ba	0.001	0.000	0.002	0.001	0.003	0.002	0.002	0.000	0.000	0.002
Pb ²⁺	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
Ca	0.001	0.001	0.001	0.001	0.000	0.001	0.000	0.000	0.000	0.000
Na	0.118	0.092	0.106	0.114	0.104	0.105	0.079	0.075	0.066	0.055
K	0.891	0.925	0.904	0.893	0.906	0.906	0.928	0.937	0.939	0.949
Rb	0.023	0.023	0.023	0.022	0.022	0.022	0.026	0.025	0.025	0.024
Cs	0.001	0.000	0.000	0.000	0.000	0.000	0.002	0.001	0.001	0.001
O	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000

Appendix D.2 (contd.): Electron microprobe analyses of K-feldspar.

Site	12-BERYL-S03F	12-BERYL-S03F	12-BERYL-S03F	12-BERYL-S03F	12-BERYL-S04	12-BERYL-S04	12-CORD-S01 (S02)	12-CORD-S01 (S02)	12-GARMUS-S01	12-GARMUS-S01
Comment	perthite	perthite	perthite	perthite	perthite	perthite	perthite	perthite	albite with ksp inclusions	albite with ksp inclusions
Point	121f-1	121f-2	122f-1	122f-2	123f-1	123f-2	124f-1	124f-2	125f-1	125f-2
P ₂ O ₅ (wt.%)	0.39	0.34	0.37	0.33	0.33	0.35	0.21	0.23	0.34	0.32
SiO ₂	63.72	63.73	63.71	63.55	63.65	63.62	63.93	63.77	64.08	63.71
TiO ₂	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
Al ₂ O ₃	18.72	18.73	18.97	18.99	18.85	18.80	19.01	18.78	18.82	18.66
MgO	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00
MnO	0.03	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01
FeO	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.02	0.00
ZnO	0.01	0.02	0.03	0.01	0.02	0.00	0.06	0.00	0.02	0.00
BaO	0.00	0.15	0.00	0.00	0.01	0.00	0.04	0.00	0.10	0.09
PbO	0.00	0.00	0.03	0.03	0.00	0.00	0.04	0.02	0.00	0.02
CaO	0.00	0.00	0.02	0.00	0.00	0.00	0.04	0.04	0.00	0.00
Na ₂ O	0.81	1.12	1.32	1.51	1.11	1.31	1.15	1.12	1.29	1.14
K ₂ O	15.78	15.35	14.90	14.83	15.31	15.05	15.32	15.36	14.98	15.29
Rb ₂ O	0.88	0.89	0.89	0.93	0.95	0.90	0.77	0.77	0.77	0.80
Cs ₂ O	0.05	0.04	0.01	0.02	0.00	0.01	0.02	0.01	0.19	0.18
Total	100.39	100.37	100.27	100.23	100.24	100.04	100.60	100.11	100.61	100.22
P (apfu)	0.015	0.013	0.014	0.013	0.013	0.014	0.008	0.009	0.013	0.013
Si	2.955	2.955	2.948	2.945	2.952	2.953	2.953	2.959	2.958	2.958
Ti	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Al	1.023	1.024	1.035	1.037	1.030	1.028	1.035	1.027	1.024	1.021
Mg	0.000	0.000	0.001	0.000	0.000	0.000	0.001	0.000	0.000	0.000
Mn ²⁺	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fe ²⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000
Zn	0.000	0.001	0.001	0.000	0.001	0.000	0.002	0.000	0.001	0.000
Ba	0.000	0.003	0.000	0.000	0.000	0.000	0.001	0.000	0.002	0.002
Pb ²⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ca	0.000	0.000	0.001	0.000	0.000	0.000	0.002	0.002	0.000	0.000
Na	0.073	0.101	0.118	0.136	0.100	0.118	0.103	0.101	0.115	0.103
K	0.933	0.908	0.880	0.877	0.906	0.891	0.903	0.909	0.882	0.906
Rb	0.026	0.027	0.026	0.028	0.028	0.027	0.023	0.023	0.023	0.024
Cs	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.004
O	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000

Appendix D.2 (contd.): Electron microprobe analyses of K-feldspar.

Site	12-GARPHOS-S04	12-GARPHOS-S04	12-GARTOUR-S01	12-GARTOUR-S01	12-LENS-PEG	12-LENS-PEG	12-LI2-S01	12-LI2-S01	12-LI2-S03	12-LI2-S03
Comment	perthite	perthite	perthite	perthite	perthite	perthite	degraded ksp	degraded ksp	perthite	perthite
Point	126f-1	126f-2	127f-1	127f-2	128f-1	128f-2	129f-1	129f-2	130f-1	130f-2
P ₂ O ₅ (wt.%)	0.57	0.56	0.35	0.35	0.33	0.33	0.05	0.07	0.49	0.52
SiO ₂	63.37	63.00	64.15	63.75	63.79	63.56	63.48	63.23	63.24	63.09
TiO ₂	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.01	0.00	0.02
Al ₂ O ₃	18.84	18.91	19.05	18.87	18.73	18.77	18.43	18.51	18.77	18.82
MgO	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00
MnO	0.00	0.00	0.01	0.00	0.00	0.02	0.01	0.00	0.00	0.00
FeO	0.01	0.03	0.03	0.02	0.03	0.00	0.03	0.02	0.02	0.02
ZnO	0.02	0.00	0.01	0.00	0.00	0.05	0.00	0.00	0.04	0.00
BaO	0.00	0.04	0.00	0.04	0.00	0.12	0.15	0.00	0.00	0.00
PbO	0.03	0.03	0.05	0.03	0.05	0.00	0.00	0.00	0.00	0.00
CaO	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Na ₂ O	1.08	0.92	1.51	1.60	0.69	0.67	0.23	0.27	1.25	1.04
K ₂ O	15.27	15.47	14.88	14.70	15.98	16.06	16.23	16.27	15.22	15.51
Rb ₂ O	0.97	1.03	0.78	0.75	0.83	0.81	1.46	1.42	0.87	0.89
Cs ₂ O	0.02	0.12	0.02	0.01	0.00	0.02	0.20	0.18	0.02	0.01
Total	100.19	100.11	100.85	100.15	100.43	100.42	100.31	99.99	99.92	99.92
P (apfu)	0.022	0.022	0.014	0.014	0.013	0.013	0.002	0.003	0.019	0.021
Si	2.941	2.934	2.950	2.951	2.957	2.952	2.972	2.967	2.942	2.938
Ti	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.001
Al	1.030	1.038	1.032	1.029	1.023	1.027	1.017	1.024	1.029	1.033
Mg	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.001	0.000	0.000
Mn ²⁺	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
Fe ²⁺	0.000	0.001	0.001	0.001	0.001	0.000	0.001	0.001	0.001	0.001
Zn	0.001	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.001	0.000
Ba	0.000	0.001	0.000	0.001	0.000	0.002	0.003	0.000	0.000	0.000
Pb ²⁺	0.000	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000
Ca	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Na	0.097	0.083	0.135	0.144	0.062	0.060	0.021	0.025	0.113	0.094
K	0.904	0.919	0.873	0.868	0.945	0.951	0.969	0.974	0.903	0.921
Rb	0.029	0.031	0.023	0.022	0.025	0.024	0.044	0.043	0.026	0.027
Cs	0.000	0.002	0.000	0.000	0.000	0.000	0.004	0.004	0.000	0.000
O	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000

Appendix D.2 (contd.): Electron microprobe analyses of K-feldspar.

Site	12-MUSC-S01	12-MUSC-S01	12-MUSC-S01	12-MUSC-S01	12-POCKET-S01	12-POCKET-S01	12-SIMPLE-S01	12-SIMPLE2-S01	12-SIMPLE2-S01	12-SIMPLE3-S01
Comment	perthite	perthite	perthite	perthite	perthite	perthite	perthite	perthite	perthite	perthite
Point	131f-1	131f-2	132f-1	132f-2	135f-1	135f-2	136f-1	137f-1	137f-2	139f-1
P ₂ O ₅ (wt.%)	0.16	0.14	0.14	0.14	0.57	0.51	0.08	0.07	0.09	0.12
SiO ₂	63.76	63.45	63.87	64.36	63.19	63.15	63.75	63.24	64.36	63.48
TiO ₂	0.01	0.01	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.00
Al ₂ O ₃	18.92	18.79	18.81	18.82	19.00	18.87	18.73	18.68	18.81	18.75
MgO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01
MnO	0.00	0.00	0.00	0.00	0.01	0.01	0.03	0.03	0.02	0.01
FeO	0.03	0.00	0.01	0.00	0.02	0.01	0.02	0.00	0.02	0.03
ZnO	0.00	0.00	0.00	0.05	0.00	0.02	0.00	0.04	0.03	0.00
BaO	0.04	0.08	0.07	0.00	0.00	0.11	0.34	0.22	0.09	0.14
PbO	0.00	0.01	0.01	0.05	0.00	0.05	0.03	0.02	0.02	0.01
CaO	0.05	0.05	0.08	0.06	0.01	0.01	0.04	0.01	0.06	0.00
Na ₂ O	0.91	0.95	2.41	2.22	1.17	1.00	1.36	0.48	1.25	0.74
K ₂ O	15.57	15.60	13.50	13.76	15.41	15.56	14.96	16.20	15.11	15.83
Rb ₂ O	0.76	0.79	0.78	0.79	0.77	0.79	0.76	0.78	0.81	0.77
Cs ₂ O	0.02	0.00	0.02	0.00	0.03	0.02	0.03	0.00	0.03	0.03
Total	100.23	99.87	99.70	100.25	100.18	100.11	100.15	99.80	100.70	99.92
P (apfu)	0.006	0.006	0.005	0.005	0.022	0.020	0.003	0.003	0.004	0.005
Si	2.957	2.957	2.960	2.966	2.932	2.937	2.963	2.960	2.969	2.961
Ti	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000
Al	1.034	1.032	1.027	1.022	1.039	1.034	1.026	1.031	1.023	1.031
Mg	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001
Mn ²⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.000
Fe ²⁺	0.001	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.001	0.001
Zn	0.000	0.000	0.000	0.002	0.000	0.001	0.000	0.001	0.001	0.000
Ba	0.001	0.001	0.001	0.000	0.000	0.002	0.006	0.004	0.002	0.003
Pb ²⁺	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000
Ca	0.002	0.002	0.004	0.003	0.000	0.000	0.002	0.001	0.003	0.000
Na	0.082	0.086	0.217	0.198	0.105	0.090	0.123	0.044	0.112	0.067
K	0.921	0.928	0.798	0.809	0.912	0.923	0.887	0.967	0.889	0.942
Rb	0.023	0.024	0.023	0.023	0.023	0.024	0.023	0.023	0.024	0.023
Cs	0.000	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.001	0.001
O	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000

Appendix D.2 (contd.): Electron microprobe analyses of K-feldspar.

Site	12-SIMPLE3-S01	12-SIMPLE4-S01	12-SIMPLE4-S01	12-SIMPLE5-S01	12-SIMPLE5-S01	12-SIMPLE6-S01	12-SIMPLE6-S01	12-SIMPLE7-S01	12-SIMPLE7-S01	12-SIMP9-S04
Comment	perthite	albite with ksp inclusions	albite with ksp inclusions	perthite	perthite	perthite	perthite	perthite	perthite	perthite
Point	139f-2	140f-1	140f-2	141f-1	141f-2	142f-1	142f-2	143f-1	143f-2	144f-1
P ₂ O ₅ (wt.%)	0.11	0.02	0.02	0.07	0.08	0.35	0.37	0.20	0.20	0.19
SiO ₂	63.30	63.92	63.79	64.47	63.52	63.16	63.44	64.24	63.90	63.42
TiO ₂	0.00	0.02	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00
Al ₂ O ₃	18.84	18.69	18.61	18.91	18.65	18.92	19.15	18.60	18.71	18.72
MgO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	0.00	0.00	0.01	0.02	0.01	0.01	0.00	0.00	0.02	0.01
FeO	0.00	0.00	0.00	0.02	0.03	0.01	0.02	0.00	0.00	0.00
ZnO	0.01	0.02	0.04	0.06	0.03	0.00	0.03	0.00	0.00	0.00
BaO	0.19	0.06	0.11	0.12	0.13	0.00	0.02	0.15	0.00	0.13
PbO	0.00	0.04	0.01	0.03	0.03	0.05	0.06	0.02	0.00	0.01
CaO	0.04	0.02	0.02	0.06	0.06	0.05	0.03	0.00	0.00	0.00
Na ₂ O	1.10	0.88	0.87	1.36	1.04	1.35	1.30	0.80	0.83	0.77
K ₂ O	15.31	15.72	15.71	14.86	15.34	15.05	15.17	15.87	15.76	15.78
Rb ₂ O	0.79	0.74	0.75	0.80	0.82	0.79	0.81	0.80	0.80	0.82
Cs ₂ O	0.04	0.02	0.00	0.02	0.04	0.02	0.03	0.03	0.02	0.01
Total	99.73	100.15	99.95	100.80	99.79	99.77	100.43	100.71	100.24	99.86
P (apfu)	0.004	0.001	0.001	0.003	0.003	0.014	0.015	0.008	0.008	0.008
Si	2.955	2.970	2.971	2.968	2.964	2.942	2.937	2.970	2.965	2.959
Ti	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Al	1.037	1.024	1.022	1.026	1.026	1.039	1.045	1.014	1.023	1.029
Mg	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mn ²⁺	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.001	0.000
Fe ²⁺	0.000	0.000	0.000	0.001	0.001	0.000	0.001	0.000	0.000	0.000
Zn	0.000	0.001	0.001	0.002	0.001	0.000	0.001	0.000	0.000	0.000
Ba	0.003	0.001	0.002	0.002	0.002	0.000	0.000	0.003	0.000	0.002
Pb ²⁺	0.000	0.001	0.000	0.000	0.000	0.001	0.001	0.000	0.000	0.000
Ca	0.002	0.001	0.001	0.003	0.003	0.002	0.001	0.000	0.000	0.000
Na	0.100	0.079	0.079	0.121	0.094	0.122	0.117	0.072	0.075	0.070
K	0.912	0.932	0.934	0.873	0.913	0.894	0.896	0.936	0.933	0.939
Rb	0.024	0.022	0.022	0.024	0.025	0.024	0.024	0.024	0.024	0.025
Cs	0.001	0.000	0.000	0.000	0.001	0.000	0.001	0.001	0.000	0.000
O	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000

Appendix D.2 (contd.): Electron microprobe analyses of K-feldspar.

Site	12-SIMP9-S04	12-SIMP9-S05 "west"	12-SIMP9-S05 "west"	12-SIMP12-S02	12-SIMP12-S02	12-SIMP13-S01	12-SIMP13-S01	12-SIMP14-S01	12-SIMP14-S01	12-SIMP15-S01
Comment	perthite	albite with ksp inclusions	albite with ksp inclusions	perthite	perthite	perthite	perthite	perthite	perthite	perthite
Point	144f-2	145f-1	145f-2	146f-1	146f-2	147f-1	147f-2	148f-1	148f-2	149f-1
P ₂ O ₅ (wt.%)	0.20	0.33	0.32	0.10	0.13	0.11	0.06	0.09	0.11	0.40
SiO ₂	64.03	63.25	63.38	63.50	64.52	64.12	63.78	63.77	64.11	63.09
TiO ₂	0.00	0.00	0.00	0.03	0.00	0.00	0.02	0.00	0.00	0.00
Al ₂ O ₃	18.89	18.86	18.75	18.83	19.01	18.57	18.61	18.69	18.95	18.92
MgO	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.00	0.01
MnO	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.01	0.01	0.00
FeO	0.00	0.00	0.00	0.01	0.05	0.01	0.02	0.00	0.00	0.04
ZnO	0.03	0.00	0.04	0.00	0.03	0.00	0.00	0.00	0.03	0.00
BaO	0.11	0.01	0.03	0.00	0.00	0.00	0.05	0.00	0.16	0.17
PbO	0.04	0.00	0.00	0.02	0.00	0.02	0.04	0.00	0.02	0.02
CaO	0.00	0.00	0.00	0.05	0.03	0.02	0.01	0.10	0.06	0.03
Na ₂ O	0.79	1.15	1.09	1.38	1.59	1.11	1.28	1.39	1.08	1.44
K ₂ O	15.84	15.31	15.44	14.87	14.57	15.33	14.98	14.87	15.25	14.87
Rb ₂ O	0.77	0.85	0.89	0.81	0.79	0.91	0.92	0.79	0.77	0.77
Cs ₂ O	0.00	0.03	0.02	0.02	0.02	0.02	0.07	0.00	0.02	0.02
Total	100.70	99.79	99.97	99.63	100.75	100.23	99.84	99.72	100.57	99.78
P (apfu)	0.008	0.013	0.013	0.004	0.005	0.004	0.002	0.004	0.004	0.016
Si	2.960	2.947	2.951	2.958	2.964	2.974	2.970	2.966	2.962	2.939
Ti	0.000	0.000	0.000	0.001	0.000	0.000	0.001	0.000	0.000	0.000
Al	1.029	1.036	1.029	1.034	1.029	1.015	1.021	1.025	1.032	1.039
Mg	0.000	0.000	0.000	0.001	0.001	0.000	0.000	0.001	0.000	0.001
Mn ²⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fe ²⁺	0.000	0.000	0.000	0.000	0.002	0.000	0.001	0.000	0.000	0.002
Zn	0.001	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.001	0.000
Ba	0.002	0.000	0.001	0.000	0.000	0.000	0.001	0.000	0.003	0.003
Pb ²⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000
Ca	0.000	0.000	0.000	0.002	0.001	0.001	0.000	0.005	0.003	0.001
Na	0.071	0.104	0.098	0.125	0.142	0.100	0.116	0.125	0.097	0.130
K	0.934	0.910	0.917	0.884	0.854	0.907	0.890	0.882	0.899	0.884
Rb	0.023	0.025	0.027	0.024	0.023	0.027	0.028	0.024	0.023	0.023
Cs	0.000	0.001	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000
O	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000

Appendix D.2 (contd.): Electron microprobe analyses of K-feldspar.

Site	12-SIMP15-S01	12-SIMP17-S01	12-SIMP17-S01	12-SKINNY-S01	12-SKINNY-S01	12-SMALL-S01-5	12-SMALL-S01-5	12-TOUR-S01	12-TOUR-S01	12-WOBBLE-S01
Comment	perthite	ksp	ksp	blue fsp (perthite)	blue fsp (perthite)	perthite	perthite	ksp	ksp	perthite
Point	149f-2	150f-1	150f-2	151f-1	151f-2	153f-1	153f-2	154f-1	154f-2	155f-1
P ₂ O ₅ (wt.%)	0.40	0.10	0.09	0.21	0.64	0.33	0.29	0.00	0.01	0.19
SiO ₂	62.66	63.26	63.86	63.15	62.61	63.47	63.64	63.51	63.52	63.38
TiO ₂	0.00	0.01	0.03	0.00	0.00	0.00	0.00	0.01	0.01	0.02
Al ₂ O ₃	18.80	18.73	18.63	18.61	18.93	18.99	18.73	18.76	18.70	18.65
MgO	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.01
MnO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
FeO	0.02	0.02	0.01	0.00	0.03	0.00	0.02	0.00	0.00	0.00
ZnO	0.01	0.02	0.04	0.00	0.00	0.05	0.07	0.03	0.00	0.04
BaO	0.00	0.00	0.02	0.00	0.12	0.00	0.00	0.42	0.57	0.08
PbO	0.03	0.02	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.01
CaO	0.03	0.07	0.07	0.00	0.00	0.00	0.01	0.02	0.02	0.03
Na ₂ O	1.10	1.34	1.40	1.09	1.11	1.59	0.98	1.03	1.00	1.05
K ₂ O	15.41	15.04	14.89	15.38	15.34	14.85	15.64	15.38	15.35	15.47
Rb ₂ O	0.80	0.77	0.80	0.85	0.87	0.84	0.79	0.77	0.76	0.78
Cs ₂ O	0.03	0.01	0.00	0.06	0.05	0.03	0.00	0.02	0.01	0.03
Total	99.29	99.39	99.88	99.37	99.70	100.15	100.18	99.95	99.95	99.75
P (apfu)	0.016	0.004	0.004	0.008	0.025	0.013	0.011	0.000	0.000	0.008
Si	2.938	2.958	2.968	2.958	2.925	2.943	2.955	2.963	2.965	2.958
Ti	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.001
Al	1.039	1.032	1.020	1.027	1.042	1.038	1.025	1.032	1.029	1.026
Mg	0.000	0.000	0.000	0.001	0.000	0.000	0.001	0.000	0.000	0.001
Mn ²⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fe ²⁺	0.001	0.001	0.000	0.000	0.001	0.000	0.001	0.000	0.000	0.000
Zn	0.000	0.001	0.001	0.000	0.000	0.002	0.002	0.001	0.000	0.001
Ba	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.008	0.010	0.001
Pb ²⁺	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ca	0.002	0.004	0.003	0.000	0.000	0.000	0.000	0.001	0.001	0.002
Na	0.100	0.121	0.126	0.099	0.101	0.143	0.088	0.093	0.091	0.095
K	0.922	0.897	0.883	0.919	0.914	0.878	0.927	0.915	0.914	0.921
Rb	0.024	0.023	0.024	0.026	0.026	0.025	0.024	0.023	0.023	0.023
Cs	0.001	0.000	0.000	0.001	0.001	0.001	0.000	0.000	0.000	0.001
O	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000

Appendix D.2 (contd.): Electron microprobe analyses of K-feldspar.

Site	12-WOBBLE-S01	12-WOBBLE-S02	12-WOBBLE-S02	12-ZONED-S01 (M01)	12-ZONED-S01 (M01)
Comment	perthite	center perthite	center perthite	core perthite	core perthite
Point	155f-2	156f-1	156f-2	157f-1	157f-2
P ₂ O ₅ (wt.%)	0.18	0.29	0.28	0.13	0.16
SiO ₂	63.33	63.42	63.11	62.95	63.77
TiO ₂	0.03	0.00	0.00	0.00	0.00
Al ₂ O ₃	18.59	18.99	18.96	18.71	18.74
MgO	0.00	0.00	0.00	0.01	0.01
MnO	0.01	0.00	0.00	0.01	0.00
FeO	0.01	0.00	0.00	0.03	0.03
ZnO	0.00	0.00	0.05	0.02	0.04
BaO	0.05	0.06	0.00	0.01	0.09
PbO	0.02	0.00	0.02	0.06	0.02
CaO	0.02	0.01	0.01	0.07	0.08
Na ₂ O	0.92	0.93	0.89	1.35	1.32
K ₂ O	15.75	15.70	15.81	15.01	14.87
Rb ₂ O	0.77	0.76	0.80	0.76	0.80
Cs ₂ O	0.02	0.01	0.02	0.01	0.02
Total	99.70	100.17	99.95	99.13	99.95
P (apfu)	0.007	0.011	0.011	0.005	0.006
Si	2.959	2.946	2.942	2.953	2.962
Ti	0.001	0.000	0.000	0.000	0.000
Al	1.024	1.040	1.042	1.034	1.026
Mg	0.000	0.000	0.000	0.001	0.001
Mn ²⁺	0.000	0.000	0.000	0.000	0.000
Fe ²⁺	0.000	0.000	0.000	0.001	0.001
Zn	0.000	0.000	0.002	0.001	0.001
Ba	0.001	0.001	0.000	0.000	0.002
Pb ²⁺	0.000	0.000	0.000	0.001	0.000
Ca	0.001	0.000	0.000	0.004	0.004
Na	0.083	0.084	0.080	0.123	0.119
K	0.939	0.930	0.940	0.898	0.881
Rb	0.023	0.023	0.024	0.023	0.024
Cs	0.000	0.000	0.000	0.000	0.000
O	8.000	8.000	8.000	8.000	8.000

Appendix D.3: Electron microprobe analyses of biotite (Bt), muscovite (Ms), and lepidolite (Lpd).

Mineral	Ms	Ms	Bt	Bt	Ms	Ms	Ms	Ms
Sample	12-PEGMA-S01	12-PEGMA-S01	12-PEGMA-S01	12-PEGMA-S01	12-PEGMA-S02	12-PEGMA-S02	12-GRANITE-S07 (M05)	12-GRANITE-S07 (M05)
Comment	muscovite	muscovite	biotite	biotite	core muscovite	core muscovite	"baby peg" muscovite	"baby peg" muscovite
Point	1m-1	1m-2	2m-1	2m-2	4m-1	4m-2	16m-1	16m-2
P ₂ O ₅ (wt.%)	0.01	0.03	0.03	0.04	0.02	0.02	0.03	0.03
SiO ₂	44.86	45.64	35.23	35.66	44.70	45.03	44.70	45.10
TiO ₂	0.69	0.76	2.47	2.47	1.01	0.94	0.76	0.67
Al ₂ O ₃	33.57	34.14	18.42	18.55	33.63	33.85	33.70	33.67
MgO	0.78	0.61	10.47	10.21	0.49	0.53	0.54	0.51
MnO	0.03	0.04	0.59	0.52	0.08	0.11	0.05	0.06
FeO	3.42	3.02	17.38	17.08	3.28	3.25	3.31	3.32
ZnO	0.02	0.00	0.08	0.11	0.01	0.00	0.00	0.01
CaO	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00
BaO	0.03	0.00	0.00	0.00	0.06	0.00	0.00	0.00
PbO	0.00	0.05	0.02	0.00	0.00	0.00	0.01	0.06
Li ₂ O**	0.07	0.04	0.12	0.13	0.11	0.08	0.05	0.03
Na ₂ O	0.74	0.65	0.10	0.10	0.78	0.78	0.70	0.76
K ₂ O	10.39	10.50	9.72	9.68	10.32	10.33	10.39	10.32
Rb ₂ O	0.60	0.63	0.46	0.52	0.57	0.59	0.63	0.61
Cs ₂ O	0.01	0.00	0.02	0.02	0.01	0.04	0.02	0.00
F	0.33	0.23	0.69	0.65	0.47	0.37	0.25	0.19
H ₂ O*	4.26	4.36	3.60	3.63	4.19	4.26	4.28	4.33
-O=F	-0.14	-0.10	-0.29	-0.27	-0.20	-0.16	-0.11	-0.08
Total	99.66	100.60	99.12	99.11	99.52	100.02	99.31	99.59
P (apfu)	0.001	0.002	0.002	0.003	0.001	0.001	0.002	0.002
Si	3.048	3.062	2.687	2.712	3.040	3.045	3.046	3.063
Ti	0.035	0.038	0.142	0.141	0.052	0.048	0.039	0.034
Al	2.689	2.700	1.656	1.663	2.696	2.698	2.707	2.695
Mg	0.079	0.061	1.191	1.157	0.050	0.053	0.055	0.052
Mn	0.002	0.002	0.038	0.033	0.005	0.006	0.003	0.003
Fe	0.194	0.169	1.109	1.086	0.187	0.184	0.189	0.189
Zn	0.001	0.000	0.005	0.006	0.001	0.000	0.000	0.001
Ca	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000
Ba	0.001	0.000	0.000	0.000	0.002	0.000	0.000	0.000
Pb	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.001
Li	0.018	0.011	0.037	0.038	0.029	0.021	0.013	0.009
Na	0.097	0.085	0.015	0.015	0.103	0.102	0.092	0.100
K	0.901	0.899	0.946	0.939	0.895	0.891	0.903	0.894
Rb	0.026	0.027	0.023	0.025	0.025	0.026	0.028	0.027
Cs	0.000	0.000	0.001	0.001	0.000	0.001	0.001	0.000
F	0.071	0.049	0.166	0.156	0.101	0.079	0.054	0.041
OH	1.929	1.951	1.834	1.844	1.899	1.921	1.946	1.959
O	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000

*Note: formula calculation based on 12 anions and (F+OH)=2.

**Note: empirical equations of Tischendorf (1997) were used to estimate Li₂O contents: equation [di1] for muscovite (Ms), equation [tri 1] for lepidolite (Lpd), and equation [tri 2] for biotite (Bt).

Appendix D.3 (contd.): Electron microprobe analyses of biotite (Bt), muscovite (Ms), and lepidolite (Lpd).

Mineral	Ms	Ms	Ms	Ms	Ms	Ms	Ms	Ms
Sample	12-BERYL-S02	12-BERYL-S02	12-BERYL-S03C	12-BERYL-S03C	12-BERYL-S03E	12-BERYL-S03E	12-BERYL-S04	12-BERYL-S04
Comment	muscovite	muscovite	"mica"	"mica"	muscovite	muscovite	mica with radiating sphere-like habit	mica with radiating sphere-like habit
Point	158m-1	158m-2	159m-1	159m-2	160m-1	160m-2	161m-1	161m-2
P ₂ O ₅ (wt.%)	0.01	0.00	0.01	0.02	0.03	0.04	0.02	0.02
SiO ₂	44.89	44.78	45.24	45.10	46.03	45.34	45.24	45.22
TiO ₂	0.12	0.07	0.41	0.35	0.14	0.14	0.13	0.15
Al ₂ O ₃	33.57	33.98	35.68	36.03	36.63	36.29	33.33	33.76
MgO	0.30	0.30	0.44	0.42	0.09	0.09	0.45	0.43
MnO	0.17	0.15	0.03	0.04	0.12	0.14	0.24	0.20
FeO	3.51	3.19	1.54	1.49	1.60	1.71	3.86	3.35
ZnO	0.00	0.00	0.02	0.00	0.02	0.03	0.05	0.01
CaO	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
BaO	0.04	0.09	0.06	0.01	0.00	0.00	0.00	0.13
PbO	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Li ₂ O**	0.11	0.08	0.28	0.26	0.03	0.05	0.06	0.06
Na ₂ O	0.35	0.41	0.89	0.88	0.92	0.93	0.45	0.42
K ₂ O	10.80	10.82	10.30	10.30	10.09	10.10	10.45	10.50
Rb ₂ O	0.73	0.76	0.64	0.60	0.78	0.75	0.77	0.74
Cs ₂ O	0.05	0.04	0.02	0.03	0.02	0.05	0.09	0.09
F	0.48	0.39	0.96	0.93	0.17	0.27	0.32	0.29
H ₂ O*	4.15	4.20	4.03	4.04	4.45	4.36	4.24	4.27
-O=F	-0.20	-0.16	-0.40	-0.39	-0.07	-0.11	-0.13	-0.12
Total	99.13	99.10	100.14	100.12	101.05	100.17	99.58	99.55
P (apfu)	0.001	0.000	0.001	0.001	0.002	0.002	0.001	0.001
Si	3.075	3.065	3.027	3.015	3.044	3.031	3.085	3.079
Ti	0.006	0.004	0.021	0.018	0.007	0.007	0.007	0.008
Al	2.710	2.741	2.814	2.839	2.855	2.859	2.679	2.709
Mg	0.031	0.031	0.044	0.042	0.009	0.009	0.046	0.044
Mn	0.010	0.009	0.002	0.002	0.007	0.008	0.014	0.012
Fe	0.201	0.183	0.086	0.083	0.088	0.096	0.220	0.191
Zn	0.000	0.000	0.001	0.000	0.001	0.001	0.003	0.001
Ca	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
Ba	0.001	0.002	0.002	0.000	0.000	0.000	0.000	0.003
Pb	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.001
Li	0.030	0.023	0.074	0.071	0.007	0.014	0.018	0.015
Na	0.046	0.054	0.115	0.114	0.118	0.121	0.060	0.055
K	0.944	0.945	0.879	0.879	0.851	0.861	0.909	0.912
Rb	0.032	0.033	0.028	0.026	0.033	0.032	0.034	0.032
Cs	0.001	0.001	0.001	0.001	0.001	0.001	0.003	0.003
F	0.104	0.084	0.203	0.197	0.036	0.057	0.069	0.062
OH	1.896	1.916	1.797	1.803	1.964	1.943	1.931	1.938
O	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000

Appendix D.3 (contd.): Electron microprobe analyses of biotite (Bt), muscovite (Ms), and lepidolite (Lpd).

Mineral	Ms	Ms	Ms	Ms	Ms	Ms	Ms	Ms
Sample	12-BERYL-S04	12-BERYL-S04	12-BERYL-S04	12-BERYL-S04	12-GAR-S01	12-GAR-S01	12-GAR-S03	12-GAR-S03
Comment	wall muscovite	wall muscovite	intermediate muscovite	intermediate muscovite	mica (center)	mica (center)	mica	mica
Point	162m-1	162m-2	163m-1	163m-2	164m-1	164m-2	165m-1	165m-2
P ₂ O ₅ (wt.%)	0.01	0.04	0.00	0.01	0.03	0.03	0.02	0.02
SiO ₂	45.22	44.91	45.94	45.39	44.90	44.93	44.64	44.84
TiO ₂	0.11	0.22	0.46	0.49	0.46	0.51	0.53	0.53
Al ₂ O ₃	35.98	36.07	35.63	35.31	34.23	34.01	33.97	33.84
MgO	0.28	0.27	0.44	0.52	0.61	0.60	0.79	0.78
MnO	0.12	0.16	0.06	0.05	0.04	0.05	0.07	0.09
FeO	1.51	1.55	1.39	1.60	3.39	3.32	2.95	3.09
ZnO	0.03	0.00	0.00	0.00	0.01	0.00	0.01	0.04
CaO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BaO	0.00	0.00	0.12	0.05	0.00	0.00	0.00	0.00
PbO	0.01	0.04	0.00	0.00	0.00	0.01	0.04	0.00
Li ₂ O**	0.09	0.14	0.29	0.33	0.10	0.07	0.11	0.12
Na ₂ O	0.75	0.75	0.87	0.81	0.77	0.81	0.77	0.78
K ₂ O	10.47	10.48	10.28	10.32	10.32	10.24	10.42	10.36
Rb ₂ O	0.62	0.60	0.63	0.59	0.58	0.58	0.59	0.63
Cs ₂ O	0.02	0.00	0.02	0.01	0.01	0.01	0.03	0.02
F	0.40	0.57	1.01	1.11	0.45	0.34	0.47	0.50
H ₂ O*	4.28	4.19	4.04	3.95	4.22	4.26	4.18	4.18
-O=F	-0.17	-0.24	-0.43	-0.47	-0.19	-0.14	-0.20	-0.21
Total	99.72	99.75	100.76	100.08	99.93	99.63	99.39	99.60
P (apfu)	0.001	0.002	0.000	0.001	0.002	0.002	0.001	0.001
Si	3.036	3.017	3.050	3.038	3.038	3.047	3.037	3.045
Ti	0.006	0.011	0.023	0.025	0.023	0.026	0.027	0.027
Al	2.847	2.856	2.788	2.785	2.730	2.719	2.724	2.708
Mg	0.028	0.027	0.044	0.052	0.062	0.061	0.080	0.079
Mn	0.007	0.009	0.003	0.003	0.002	0.003	0.004	0.005
Fe	0.085	0.087	0.077	0.090	0.192	0.188	0.168	0.175
Zn	0.001	0.000	0.000	0.000	0.000	0.000	0.001	0.002
Ca	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ba	0.000	0.000	0.003	0.001	0.000	0.000	0.000	0.000
Pb	0.000	0.001	0.000	0.000	0.000	0.000	0.001	0.000
Li	0.023	0.037	0.079	0.090	0.027	0.019	0.029	0.032
Na	0.098	0.098	0.112	0.105	0.101	0.107	0.102	0.103
K	0.897	0.898	0.871	0.881	0.891	0.886	0.904	0.897
Rb	0.027	0.026	0.027	0.025	0.025	0.025	0.026	0.027
Cs	0.001	0.000	0.001	0.000	0.000	0.000	0.001	0.001
F	0.085	0.121	0.212	0.235	0.096	0.073	0.101	0.107
OH	1.915	1.879	1.788	1.765	1.904	1.927	1.899	1.893
O	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000

Appendix D.3 (contd.): Electron microprobe analyses of biotite (Bt), muscovite (Ms), and lepidolite (Lpd).

Mineral	Ms	Ms	Ms	Ms	Ms	Ms	Lpd	Lpd
Sample	12-GARPHOS-S04	12-GARPHOS-S04	12-GARTOUR-S01	12-GARTOUR-S01	12-GARTOUR-S01	12-GARTOUR-S01	12-Li-S01	12-Li-S01
Comment	muscovite	muscovite	muscovite	muscovite	muscovite from pocket	muscovite from pocket	lepidolite	lepidolite
Point	166m-1	166m-2	167m-1	167m-2	168m-1	168m-2	169m-1	169m-2
P ₂ O ₅ (wt.%)	0.03	0.02	0.02	0.03	0.03	0.03	0.04	0.04
SiO ₂	45.33	44.53	45.27	45.56	46.06	44.99	51.69	50.50
TiO ₂	0.40	0.40	0.27	0.25	0.04	0.06	0.00	0.00
Al ₂ O ₃	34.58	34.43	35.89	37.03	36.70	36.46	27.28	26.78
MgO	0.30	0.31	0.32	0.25	0.26	0.33	0.00	0.01
MnO	0.08	0.06	0.04	0.04	0.02	0.03	0.42	0.37
FeO	3.45	3.30	1.64	1.30	0.95	0.95	0.02	0.02
ZnO	0.00	0.05	0.01	0.06	0.00	0.01	0.03	0.01
CaO	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.02
BaO	0.00	0.07	0.00	0.00	0.00	0.00	0.04	0.00
PbO	0.00	0.04	0.00	0.02	0.03	0.00	0.00	0.01
Li ₂ O**	0.21	0.19	0.05	0.03	0.00	0.00	5.28	4.94
Na ₂ O	0.77	0.70	0.77	0.69	0.74	0.76	0.40	0.39
K ₂ O	10.19	10.39	10.34	10.34	10.23	10.34	10.59	10.63
Rb ₂ O	0.63	0.64	0.56	0.63	0.59	0.60	1.56	1.59
Cs ₂ O	0.04	0.03	0.00	0.02	0.01	0.03	0.30	0.26
F	0.78	0.72	0.26	0.17	0.00	0.00	6.24	5.56
H ₂ O*	4.09	4.07	4.35	4.45	4.52	4.45	1.69	1.90
-O=F	-0.33	-0.30	-0.11	-0.07	0.00	0.00	-2.63	-2.34
Total	100.55	99.64	99.67	100.79	100.19	99.04	102.95	100.69
P (apfu)	0.002	0.001	0.001	0.002	0.002	0.002	0.002	0.002
Si	3.045	3.027	3.037	3.017	3.056	3.028	3.336	3.337
Ti	0.020	0.020	0.014	0.012	0.002	0.003	0.000	0.000
Al	2.738	2.758	2.838	2.890	2.870	2.892	2.075	2.086
Mg	0.030	0.031	0.032	0.025	0.026	0.033	0.000	0.001
Mn	0.005	0.003	0.002	0.002	0.001	0.002	0.023	0.021
Fe	0.194	0.188	0.092	0.072	0.053	0.053	0.001	0.001
Zn	0.000	0.003	0.000	0.003	0.000	0.000	0.001	0.000
Ca	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.001
Ba	0.000	0.002	0.000	0.000	0.000	0.000	0.001	0.000
Pb	0.000	0.001	0.000	0.000	0.001	0.000	0.000	0.000
Li	0.056	0.051	0.013	0.007	0.000	0.000	1.371	1.312
Na	0.100	0.092	0.100	0.089	0.095	0.099	0.050	0.050
K	0.873	0.901	0.885	0.874	0.866	0.888	0.872	0.896
Rb	0.027	0.028	0.024	0.027	0.025	0.026	0.065	0.068
Cs	0.001	0.001	0.000	0.001	0.000	0.001	0.008	0.007
F	0.166	0.155	0.055	0.036	0.000	0.000	1.274	1.162
OH	1.834	1.845	1.945	1.964	2.000	2.000	0.726	0.838
O	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000

Appendix D.3 (contd.): Electron microprobe analyses of biotite (Bt), muscovite (Ms), and lepidolite (Lpd).

Mineral	Lpd	Lpd	Ms	Ms	Lpd	Lpd	Lpd	Lpd
Sample	12-LI2-S01	12-LI2-S01	12-LI2-S02C	12-LI2-S02C	12-LI2-S02DE	12-LI2-S02DE	12-LI2-S02DE	12-LI2-S02DE
Comment	lepidolite	lepidolite	muscovite	muscovite	muscovite next to green tur	muscovite next to green tur	lepidolite	lepidolite
Point	170m-1	170m-2	171m-1	171m-2	172m-1	172m-2	173m-1	173m-2
P ₂ O ₅ (wt.%)	0.05	0.01	0.02	0.03	0.04	0.00	0.01	0.03
SiO ₂	49.64	49.81	44.76	45.19	53.03	53.21	51.03	51.10
TiO ₂	0.04	0.00	0.75	0.78	0.05	0.03	0.01	0.00
Al ₂ O ₃	28.73	28.27	33.31	34.16	25.24	25.35	27.12	27.23
MgO	0.00	0.01	0.83	0.80	0.01	0.01	0.00	0.00
MnO	1.06	1.04	0.05	0.03	0.87	0.86	0.59	0.66
FeO	0.04	0.01	2.60	2.52	0.08	0.10	0.05	0.05
ZnO	0.02	0.06	0.04	0.00	0.00	0.04	0.03	0.00
CaO	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
BaO	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
PbO	0.00	0.01	0.02	0.03	0.01	0.06	0.00	0.01
Li ₂ O**	4.69	4.74	0.12	0.15	5.67	5.72	5.09	5.11
Na ₂ O	0.28	0.29	0.70	0.67	0.24	0.19	0.27	0.30
K ₂ O	10.74	10.83	10.35	10.38	10.80	10.91	10.50	10.44
Rb ₂ O	1.45	1.49	0.60	0.60	1.52	1.48	1.61	1.50
Cs ₂ O	0.33	0.37	0.03	0.00	0.26	0.28	0.72	0.71
F	5.67	6.26	0.51	0.60	7.17	7.28	6.53	6.38
H ₂ O*	1.90	1.61	4.14	4.16	1.25	1.22	1.50	1.58
-O=F	-2.39	-2.64	-0.21	-0.25	-3.02	-3.07	-2.75	-2.69
Total	102.25	102.17	98.63	99.85	103.22	103.67	102.32	102.41
P (apfu)	0.003	0.001	0.001	0.002	0.002	0.000	0.001	0.002
Si	3.245	3.264	3.062	3.048	3.417	3.416	3.332	3.329
Ti	0.002	0.000	0.039	0.040	0.002	0.001	0.000	0.000
Al	2.214	2.184	2.686	2.715	1.917	1.918	2.087	2.091
Mg	0.000	0.001	0.085	0.080	0.001	0.001	0.000	0.000
Mn	0.059	0.058	0.003	0.002	0.047	0.047	0.033	0.036
Fe	0.002	0.001	0.149	0.142	0.004	0.005	0.003	0.003
Zn	0.001	0.003	0.002	0.000	0.000	0.002	0.001	0.000
Ca	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000
Ba	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Pb	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.000
Li	1.232	1.249	0.033	0.040	1.469	1.477	1.336	1.339
Na	0.035	0.037	0.093	0.088	0.030	0.024	0.034	0.038
K	0.896	0.905	0.903	0.893	0.888	0.894	0.875	0.868
Rb	0.061	0.063	0.026	0.026	0.063	0.061	0.068	0.063
Cs	0.009	0.010	0.001	0.000	0.007	0.008	0.020	0.020
F	1.172	1.298	0.110	0.128	1.461	1.478	1.348	1.314
OH	0.828	0.702	1.890	1.872	0.539	0.522	0.652	0.686
O	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000

Appendix D.3 (contd.): Electron microprobe analyses of biotite (Bt), muscovite (Ms), and lepidolite (Lpd).

Mineral	Ms	Ms	Ms	Ms	Ms	Ms	Ms	Ms
Sample	12-MUSC-S01	12-MUSC-S01	12-SIMPLE-S01	12-SIMPLE-S01	12-SIMP9-S04	12-SIMP9-S04	12-SIMP9-S04	12-SIMP9-S04
Comment							muscovite (center)	muscovite (center)
	mica	mica	mica	mica	mica	mica		
Point	174m-1	174m-2	175m-1	175m-2	176m-1	176m-2	177m-1	177m-2
P ₂ O ₅ (wt.%)	0.01	0.00	0.00	0.02	0.08	0.03	0.05	0.01
SiO ₂	44.61	44.96	45.82	45.62	44.69	44.78	45.31	45.61
TiO ₂	0.54	0.63	0.54	0.56	0.62	0.75	0.53	0.65
Al ₂ O ₃	33.40	33.64	34.13	33.94	34.47	34.63	35.13	34.73
MgO	0.66	0.65	0.86	0.87	0.64	0.63	0.49	0.57
MnO	0.03	0.05	0.02	0.00	0.03	0.04	0.05	0.06
FeO	3.58	3.66	2.92	3.03	3.02	2.99	2.89	2.90
ZnO	0.01	0.07	0.00	0.04	0.05	0.00	0.01	0.06
CaO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BaO	0.00	0.00	0.16	0.02	0.08	0.07	0.03	0.01
PbO	0.03	0.02	0.00	0.05	0.00	0.02	0.02	0.00
Li ₂ O**	0.04	0.03	0.03	0.00	0.04	0.02	0.04	0.05
Na ₂ O	0.70	0.74	0.71	0.70	0.82	0.79	0.72	0.71
K ₂ O	10.48	10.49	10.53	10.41	10.27	10.34	10.34	10.36
Rb ₂ O	0.60	0.59	0.53	0.53	0.60	0.59	0.57	0.57
Cs ₂ O	0.00	0.04	0.05	0.02	0.03	0.02	0.03	0.01
F	0.21	0.19	0.18	0.00	0.23	0.13	0.23	0.28
H ₂ O*	4.28	4.33	4.39	4.46	4.32	4.38	4.37	4.35
-O=F	-0.09	-0.08	-0.08	0.00	-0.10	-0.05	-0.10	-0.12
Total	99.09	100.01	100.80	100.27	99.90	100.16	100.72	100.82
P (apfu)	0.001	0.000	0.000	0.001	0.005	0.002	0.003	0.001
Si	3.053	3.050	3.069	3.069	3.023	3.021	3.032	3.048
Ti	0.028	0.032	0.027	0.028	0.032	0.038	0.027	0.033
Al	2.694	2.690	2.694	2.691	2.748	2.753	2.770	2.736
Mg	0.067	0.066	0.086	0.087	0.065	0.063	0.049	0.057
Mn	0.002	0.003	0.001	0.000	0.002	0.002	0.003	0.003
Fe	0.205	0.208	0.164	0.170	0.171	0.169	0.162	0.162
Zn	0.001	0.004	0.000	0.002	0.002	0.000	0.000	0.003
Ca	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ba	0.000	0.000	0.004	0.001	0.002	0.002	0.001	0.000
Pb	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.000
Li	0.010	0.009	0.008	0.000	0.011	0.005	0.011	0.014
Na	0.093	0.097	0.092	0.091	0.108	0.103	0.093	0.092
K	0.915	0.908	0.900	0.893	0.886	0.890	0.883	0.883
Rb	0.026	0.026	0.023	0.023	0.026	0.026	0.025	0.024
Cs	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.000
F	0.045	0.041	0.038	0.000	0.049	0.028	0.049	0.059
OH	1.955	1.959	1.962	2.000	1.951	1.972	1.951	1.941
O	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000

Appendix D.3 (contd.): Electron microprobe analyses of biotite (Bt), muscovite (Ms), and lepidolite (Lpd).

Mineral	Ms	Ms	Ms	Ms	Ms	Ms	Ms	Ms
Sample	12-SIMP9-S05 "west"	12-SIMP9-S05 "west"	12-SKINNY-S01	12-SKINNY-S01	12-TOUR-S01-2	12-TOUR-S01-2	12-TOURMUS-S01 (M01)	12-TOURMUS-S01 (M01)
Comment	muscovite	muscovite	"ball mica" mica with sphere-like radial habit	"ball mica" mica with sphere-like radial habit	muscovite	muscovite	muscovite	muscovite
Point	178m-1	178m-2	179m-1	179m-2	180m-1	180m-2	181m-1	181m-2
P ₂ O ₅ (wt.%)	0.04	0.03	0.00	0.03	0.01	0.03	0.02	0.04
SiO ₂	45.29	44.72	45.54	44.67	45.74	45.67	44.89	44.58
TiO ₂	0.60	0.50	0.05	0.00	0.27	0.31	0.23	0.30
Al ₂ O ₃	35.05	34.51	34.81	33.11	36.43	36.57	35.16	34.67
MgO	0.14	0.15	0.34	0.37	0.11	0.12	0.11	0.12
MnO	0.10	0.16	0.06	0.07	0.01	0.02	0.12	0.15
FeO	3.03	2.83	1.50	1.62	1.45	1.54	2.67	2.80
ZnO	0.04	0.03	0.04	0.04	0.02	0.07	0.04	0.00
CaO	0.00	0.03	0.03	0.03	0.00	0.01	0.00	0.00
BaO	0.00	0.01	0.00	0.00	0.08	0.16	0.00	0.00
PbO	0.00	0.04	0.01	0.00	0.01	0.00	0.02	0.00
Li ₂ O**	0.00	0.02	0.01	0.02	0.01	0.02	0.37	0.45
Na ₂ O	0.85	0.65	0.10	0.07	0.90	0.93	0.88	0.91
K ₂ O	9.95	10.26	10.12	9.29	9.95	9.96	10.14	10.09
Rb ₂ O	0.63	0.68	0.60	0.63	0.65	0.62	0.71	0.74
Cs ₂ O	0.01	0.04	0.01	0.01	0.01	0.02	0.01	0.04
F	0.03	0.14	0.08	0.13	0.05	0.15	1.20	1.38
H ₂ O*	4.45	4.34	4.36	4.20	4.48	4.44	3.88	3.76
-O=F	-0.01	-0.06	-0.03	-0.05	-0.02	-0.06	-0.51	-0.58
Total	100.20	99.08	97.63	94.23	100.15	100.58	99.94	99.45
P (apfu)	0.002	0.002	0.000	0.002	0.001	0.002	0.001	0.002
Si	3.042	3.046	3.105	3.146	3.046	3.033	3.027	3.025
Ti	0.030	0.026	0.003	0.000	0.014	0.015	0.012	0.015
Al	2.775	2.770	2.797	2.748	2.859	2.862	2.794	2.773
Mg	0.014	0.015	0.035	0.039	0.011	0.012	0.011	0.012
Mn	0.006	0.009	0.003	0.004	0.001	0.001	0.007	0.009
Fe	0.170	0.161	0.086	0.095	0.081	0.086	0.151	0.159
Zn	0.002	0.002	0.002	0.002	0.001	0.003	0.002	0.000
Ca	0.000	0.002	0.002	0.002	0.000	0.001	0.000	0.000
Ba	0.000	0.000	0.000	0.000	0.002	0.004	0.000	0.000
Pb	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Li	0.001	0.006	0.003	0.005	0.001	0.006	0.100	0.121
Na	0.111	0.086	0.013	0.010	0.116	0.120	0.115	0.120
K	0.853	0.891	0.880	0.835	0.845	0.844	0.872	0.874
Rb	0.027	0.030	0.026	0.029	0.028	0.026	0.031	0.032
Cs	0.000	0.001	0.000	0.000	0.000	0.001	0.000	0.001
F	0.006	0.030	0.017	0.029	0.011	0.032	0.256	0.296
OH	1.994	1.970	1.983	1.971	1.989	1.968	1.744	1.704
O	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000

Appendix D.3 (contd.): Electron microprobe analyses of biotite (Bt), muscovite (Ms), and lepidolite (Lpd).

Mineral	Bt	Bt	Bt	Bt	Bt	Bt	Bt	Bt
Sample	12-BERYL-S03A	12-BERYL-S03A	12-BERYL-S03B	12-BERYL-S03B	12-BERYL-S03C	12-BERYL-S03C	12-BERYL-S04	12-BERYL-S04
Comment	biotite	biotite	biotite	biotite	biotite	biotite	biotite	biotite
Point	182m-1	182m-2	183m-1	183m-2	184m-1	184m-2	185m-1	185m-2
P ₂ O ₅ (wt.%)	0.00	0.02	0.01	0.01	0.01	0.00	0.01	0.03
SiO ₂	34.24	34.76	34.79	34.91	37.77	37.38	34.57	34.11
TiO ₂	2.53	2.58	2.60	2.57	1.68	1.38	2.48	2.45
Al ₂ O ₃	19.53	19.46	19.54	19.62	20.07	20.33	20.25	19.77
MgO	6.70	6.86	6.67	6.61	3.68	3.60	5.70	5.71
MnO	0.43	0.42	0.45	0.45	0.83	0.81	0.48	0.53
FeO	20.86	20.76	20.04	20.21	20.07	20.79	20.79	21.06
ZnO	0.05	0.05	0.06	0.10	0.00	0.11	0.05	0.09
CaO	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.02
BaO	0.00	0.14	0.00	0.00	0.11	0.04	0.00	0.06
PbO	0.00	0.00	0.00	0.03	0.00	0.04	0.01	0.00
Li ₂ O**	0.25	0.24	0.25	0.26	0.54	0.55	0.32	0.32
Na ₂ O	0.20	0.21	0.30	0.29	0.07	0.07	0.31	0.32
K ₂ O	9.54	9.45	9.28	9.19	9.64	9.67	9.54	9.46
Rb ₂ O	0.49	0.53	0.49	0.49	0.82	0.76	0.50	0.48
Cs ₂ O	0.01	0.02	0.03	0.02	0.31	0.28	0.03	0.02
F	1.58	1.88	2.35	2.50	1.50	1.28	0.95	1.00
H ₂ O*	3.11	3.00	2.76	2.70	3.22	3.32	3.43	3.36
-O=F	-0.67	-0.79	-0.99	-1.05	-0.63	-0.54	-0.40	-0.42
Total	98.86	99.59	98.63	98.90	99.69	99.89	99.03	98.37
P (apfu)	0.000	0.001	0.001	0.001	0.001	0.000	0.001	0.002
Si	2.660	2.678	2.694	2.696	2.881	2.855	2.674	2.666
Ti	0.148	0.150	0.151	0.149	0.096	0.079	0.144	0.144
Al	1.788	1.767	1.783	1.786	1.804	1.830	1.846	1.821
Mg	0.776	0.788	0.770	0.761	0.418	0.410	0.657	0.665
Mn	0.028	0.027	0.030	0.029	0.054	0.052	0.031	0.035
Fe	1.355	1.338	1.298	1.305	1.280	1.328	1.345	1.377
Zn	0.003	0.003	0.003	0.006	0.000	0.006	0.003	0.005
Ca	0.000	0.000	0.000	0.000	0.000	0.002	0.002	0.002
Ba	0.000	0.004	0.000	0.000	0.003	0.001	0.000	0.002
Pb	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.000
Li	0.079	0.076	0.079	0.080	0.166	0.170	0.098	0.099
Na	0.030	0.031	0.045	0.043	0.010	0.010	0.046	0.048
K	0.945	0.929	0.917	0.905	0.938	0.942	0.941	0.943
Rb	0.024	0.026	0.024	0.024	0.040	0.037	0.025	0.024
Cs	0.000	0.001	0.001	0.001	0.010	0.009	0.001	0.001
F	0.388	0.458	0.575	0.611	0.362	0.309	0.232	0.247
OH	1.612	1.542	1.425	1.389	1.638	1.691	1.768	1.753
O	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000

Appendix D.3 (contd.): Electron microprobe analyses of biotite (Bt), muscovite (Ms), and lepidolite (Lpd).

Mineral	Bt	Bt	Bt	Bt	Bt	Bt	Bt	Bt
Sample	12-LI2-S02C	12-LI2-S02C	12-SIMPLE2-S01	12-SIMPLE2-S01	12-POCKET-S01	12-POCKET-S01	12-SIMP14-S01	12-SIMP14-S01
Comment	biotite	biotite	biotite	biotite	border zone biotite	border zone biotite	biotite	biotite
Point	186m-1	186m-2	187m-1	187m-2	188m-1	188m-2	189m-1	189m-2
P ₂ O ₅ (wt.%)	0.02	0.01	0.01	0.01	0.02	0.01	0.02	0.00
SiO ₂	35.49	35.51	35.27	35.69	34.36	34.60	34.57	34.10
TiO ₂	2.23	2.29	2.17	2.12	2.79	2.74	1.72	1.82
Al ₂ O ₃	19.11	19.14	18.47	18.53	19.60	19.43	20.04	19.78
MgO	7.15	7.18	11.03	10.91	8.02	7.92	7.13	7.13
MnO	1.47	1.46	0.30	0.31	0.34	0.38	0.53	0.54
FeO	18.44	18.68	16.57	16.67	19.26	19.25	21.29	21.11
ZnO	0.05	0.07	0.00	0.04	0.06	0.05	0.02	0.07
CaO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
BaO	0.00	0.00	0.05	0.06	0.13	0.06	0.02	0.16
PbO	0.02	0.04	0.05	0.02	0.00	0.00	0.00	0.00
Li ₂ O**	0.23	0.23	0.11	0.11	0.19	0.20	0.23	0.23
Na ₂ O	0.17	0.21	0.17	0.19	0.16	0.20	0.19	0.20
K ₂ O	9.36	9.43	9.61	9.60	9.42	9.43	9.36	9.31
Rb ₂ O	0.56	0.51	0.51	0.49	0.45	0.51	0.43	0.46
Cs ₂ O	0.00	0.02	0.03	0.01	0.02	0.03	0.00	0.02
F	1.52	1.33	0.85	0.80	0.24	0.21	0.35	0.29
H ₂ O*	3.16	3.26	3.52	3.56	3.78	3.79	3.73	3.72
-O=F	-0.64	-0.56	-0.36	-0.34	-0.10	-0.09	-0.15	-0.12
Total	98.34	98.81	98.35	98.78	98.74	98.72	99.48	98.83
P (apfu)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000
Si	2.743	2.735	2.699	2.716	2.648	2.666	2.662	2.650
Ti	0.130	0.133	0.125	0.121	0.162	0.159	0.100	0.106
Al	1.741	1.738	1.666	1.662	1.780	1.765	1.819	1.812
Mg	0.824	0.825	1.258	1.238	0.921	0.910	0.818	0.826
Mn	0.096	0.095	0.019	0.020	0.022	0.025	0.035	0.036
Fe	1.192	1.203	1.060	1.061	1.241	1.240	1.371	1.372
Zn	0.003	0.004	0.000	0.002	0.003	0.003	0.001	0.004
Ca	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
Ba	0.000	0.000	0.001	0.002	0.004	0.002	0.001	0.005
Pb	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000
Li	0.071	0.071	0.033	0.034	0.060	0.061	0.072	0.072
Na	0.025	0.031	0.025	0.028	0.024	0.030	0.028	0.030
K	0.923	0.927	0.938	0.932	0.926	0.927	0.919	0.923
Rb	0.028	0.025	0.025	0.024	0.022	0.025	0.021	0.023
Cs	0.000	0.001	0.001	0.000	0.001	0.001	0.000	0.001
F	0.372	0.324	0.206	0.193	0.058	0.051	0.085	0.071
OH	1.628	1.676	1.794	1.807	1.942	1.949	1.915	1.929
O	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000

Appendix D.4: Electron microprobe analyses of beryl.

Sample site	12-BERYL-S01		12-BERYL-S01				
Point	B1-1	B1-2	B1-3	B2-8	B2-9	B2-10	B2-11
Description	white primary beryl	white primary beryl	white primary beryl	white primary beryl	white primary beryl	white primary beryl	white primary beryl
SiO ₂	65.18	64.94	65.46	63.61	66.43	64.48	65.32
Al ₂ O ₃	18.68	18.30	18.55	18.40	18.65	18.64	18.70
BeO [¶]	13.54	13.47	13.55	13.27	13.73	13.46	13.57
MgO	--	--	--	--	--	--	--
MnO	--	--	--	0.11	--	--	--
FeO	0.22	0.31	0.28	0.26	0.22	0.30	0.27
Li ₂ O*	0.05	0.04	0.07	0.04	0.06	0.03	0.05
Na ₂ O	0.22	0.23	0.27	0.27	0.25	0.22	0.24
K ₂ O	--	--	--	--	--	--	--
Cs ₂ O	--	--	0.16	--	--	--	--
H ₂ O [§]	1.02	1.03	1.07	1.07	1.05	1.02	1.04
Total	98.91	98.32	99.41	97.03	100.39	98.15	99.19
Si ⁴⁺	5.973	5.990	5.983	5.955	5.998	5.959	5.972
Al ³⁺	2.018	1.989	1.998	2.030	1.985	2.030	2.015
Be ²⁺	2.982	2.985	2.974	2.985	2.978	2.989	2.982
Mg ²⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mn ²⁺	0.000	0.000	0.000	0.009	0.000	0.000	0.000
Fe ²⁺	0.017	0.024	0.021	0.020	0.017	0.023	0.021
Li ⁺	0.018	0.015	0.026	0.015	0.022	0.011	0.018
Na ⁺	0.039	0.041	0.048	0.049	0.044	0.039	0.043
K ⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cs ⁺	0.000	0.000	0.006	0.000	0.000	0.000	0.000
H ₂ O	0.185	0.186	0.192	0.192	0.189	0.185	0.188
Cation sum	11.047	11.044	11.056	11.063	11.044	11.051	11.051

*Determined by stoichiometry, where Li = (Na + K + Cs) - (Mg + Fe + Mn)

[¶]BeO calculated assuming 3 (Be⁺², Li⁺)

[§]calculated after Giuliani *et al.* (1997)

Normalized on a basis of 18 anions

Other elements sought but found to be below detection limits include: Ca, Sc, Ti, V, and Cr.

Appendix D.4 (contd.): Electron microprobe analyses of beryl.

Sample site	12-BERYL-S01			12-GAR-S01			
Point	22be-1	22be-2	22be-3	GR2-1	GR3-1	GR3-2	GR3-3
Description	acicular secondary beryl	acicular secondary beryl	acicular secondary beryl	microscopic beryl replacing cordierite	microscopic beryl replacing cordierite	microscopic beryl replacing cordierite	microscopic beryl replacing cordierite
SiO ₂	66.36	66.04	65.86	65.52	65.85	66.19	66.60
Al ₂ O ₃	18.52	18.49	18.60	18.25	18.06	18.27	18.00
BeO [¶]	13.80	13.70	13.69	13.76	13.75	13.81	13.85
MgO	--	--	--	0.31	0.31	0.22	0.29
MnO	--	--	--	0.20	--	--	--
FeO	0.37	0.34	0.34	0.98	0.72	0.65	0.60
Li ₂ O*	0.01	0.03	0.03	--	--	--	--
Na ₂ O	0.19	0.22	0.22	0.48	0.48	0.39	0.45
K ₂ O	--	--	--	0.04	0.03	--	--
Cs ₂ O	--	--	--	--	--	--	--
H ₂ O [§]	1.00	1.02	1.02	1.25	1.25	1.17	1.22
Total	100.25	99.84	99.76	100.79	100.45	100.70	101.01
Si ⁴⁺	5.999	5.996	5.986	5.948	5.980	5.984	6.004
Al ³⁺	1.973	1.979	1.992	1.952	1.933	1.947	1.912
Be ²⁺	2.996	2.989	2.989	3.000	3.000	3.000	3.000
Mg ²⁺	0.000	0.000	0.000	0.042	0.042	0.030	0.039
Mn ²⁺	0.000	0.000	0.000	0.015	0.000	0.000	0.000
Fe ²⁺	0.028	0.026	0.026	0.074	0.055	0.049	0.045
Li ⁺	0.004	0.011	0.011	0.000	0.000	0.000	0.000
Na ⁺	0.033	0.039	0.039	0.084	0.085	0.068	0.079
K ⁺	0.000	0.000	0.000	0.005	0.003	0.000	0.000
Cs ⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000
H ₂ O	0.180	0.185	0.185	0.224	0.224	0.211	0.220
Cation sum	11.033	11.039	11.043	11.120	11.098	11.078	11.079

Appendix D.4 (contd.): Electron microprobe analyses of beryl.

Sample site	12-GAR-S01-4		12-GAR-S01-5		12-GARMUS-S01		
Point	GR4-3	GR4-2	GR5-1	GR5-2	26be-1	26be-2	26be-3
Description	microscopic beryl replacing cordierite	microscopic beryl replacing cordierite	microscopic beryl replacing cordierite	microscopic beryl replacing cordierite	white primary beryl	white primary beryl	white primary beryl
SiO ₂	63.65	65.84	65.47	65.05	66.25	65.54	65.80
Al ₂ O ₃	17.93	17.72	17.73	17.79	18.06	17.83	17.91
BeO [¶]	13.30	13.71	13.64	13.58	13.8*	13.64*	13.69*
MgO	0.30	0.41	0.25	0.26	0.14	0.15	0.13
MnO	--	--	--	--	--	--	--
FeO	0.59	0.62	0.93	0.87	0.88	0.75	0.75
Li ₂ O*	0.03	--	--	--	--	--	--
Na ₂ O	0.46	0.57	0.39	0.47	0.40	0.40	0.38
K ₂ O	--	--	--	--	--	--	--
Cs ₂ O	0.07	--	--	--	0.16	0.18	0.17
H ₂ O [§]	1.23	1.32	1.17	1.24	1.18	1.18	1.16
Total	97.56	100.19	99.58	99.26	100.87	99.67	99.99
Si ⁴⁺	5.955	5.997	5.995	5.982	5.994	5.999	6.000
Al ³⁺	1.977	1.902	1.913	1.928	1.926	1.923	1.925
Be ²⁺	2.989	3.000	3.000	3.000	3.000	3.000	3.000
Mg ²⁺	0.042	0.056	0.034	0.036	0.019	0.020	0.018
Mn ²⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fe ²⁺	0.046	0.047	0.071	0.067	0.067	0.057	0.057
Li ⁺	0.011	0.000	0.000	0.000	0.000	0.001	0.000
Na ⁺	0.083	0.101	0.069	0.084	0.070	0.071	0.067
K ⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cs ⁺	0.003	0.000	0.000	0.000	0.006	0.007	0.007
H ₂ O	0.221	0.238	0.211	0.223	0.212	0.212	0.209
Cation sum	11.106	11.103	11.082	11.097	11.081	11.078	11.074

Appendix D.4 (contd.): Electron microprobe analyses of beryl.

Sample site	12-GARMUS-S01			12-GARPHOS-S04		12-LI2-S02C	
Point	GM1-8	GM1-9	GM1-10	244be-1	244be-2	245be-1	245be-2
Description	pale blue primary beryl	pale blue primary beryl	pale blue primary beryl	white primary beryl	white primary beryl	white primary beryl	white primary beryl
SiO ₂	65.68	64.72	65.45	66.03	66.48	65.92	65.70
Al ₂ O ₃	17.95	18.33	18.35	18.66	18.46	17.91	18.04
BeO [¶]	13.68	13.51	13.62	13.71	13.83	13.72 [*]	13.7 [*]
MgO	0.12	0.06	0.06	--	0.01	0.16	0.15
MnO	--	--	--	--	--	--	--
FeO	0.76	0.53	0.57	0.30	0.39	0.78	0.78
Li ₂ O [*]	--	0.02	0.03	0.04	--	--	--
Na ₂ O	0.36	0.30	0.35	0.21	0.17	0.38	0.36
K ₂ O	0.02	--	--	--	--	--	--
Cs ₂ O	0.23	0.15	0.13	0.11	--	--	--
H ₂ O [§]	1.14	1.09	1.13	1.02	0.98	1.16	1.14
Total	99.94	98.71	99.69	100.08	100.32	100.03	99.87
Si ⁴⁺	5.996	5.968	5.979	5.987	6.004	6.001	5.990
Al ³⁺	1.931	1.992	1.975	1.994	1.965	1.922	1.939
Be ²⁺	3.000	2.993	2.989	2.985	3.000	3.000	3.000
Mg ²⁺	0.016	0.008	0.008	0.000	0.001	0.022	0.020
Mn ²⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fe ²⁺	0.058	0.041	0.044	0.023	0.029	0.059	0.059
Li ⁺	0.000	0.007	0.011	0.015	0.000	0.000	0.000
Na ⁺	0.064	0.054	0.062	0.037	0.030	0.067	0.064
K ⁺	0.002	0.000	0.000	0.000	0.000	0.000	0.000
Cs ⁺	0.009	0.006	0.005	0.004	0.000	0.000	0.000
H ₂ O	0.206	0.197	0.204	0.183	0.177	0.209	0.206
Cation sum	11.076	11.069	11.070	11.045	11.029	11.071	11.072

Appendix D.4 (contd.): Electron microprobe analyses of beryl.

Sample site	12-SIMPLE9-S05			12-SIMPLE9-S05 "west"			
Point	24be-1	24be-2	24be-3	25be-1	25be-2	25be-3	246be-1
Description	white primary beryl	white primary beryl	white primary beryl	white primary beryl	white primary beryl	white primary beryl	white primary beryl
SiO ₂	66.23	65.95	65.70	65.76	66.33	66.10	66.32
Al ₂ O ₃	18.37	18.14	18.26	18.37	18.32	18.56	17.94
BeO [¶]	13.77*	13.72*	13.69*	13.7*	13.78*	13.79*	13.76*
MgO	0.02	0.07	0.04	0.02	0.02	0.03	0.05
MnO	--	--	--	--	--	--	--
FeO	0.41	0.58	0.66	0.50	0.38	0.44	0.70
Li ₂ O*	--	--	--	--	--	--	--
Na ₂ O	0.14	0.23	0.19	0.15	0.14	0.18	0.23
K ₂ O	--	--	--	--	--	--	--
Cs ₂ O	0.03	0.05	0.00	0.04	0.00	0.06	--
H ₂ O [§]	0.96	1.03	1.00	0.96	0.96	0.99	1.03
Total	99.93	99.77	99.54	99.50	99.93	100.15	100.03
Si ⁴⁺	6.005	6.003	5.992	5.993	6.011	5.987	6.020
Al ³⁺	1.963	1.946	1.963	1.973	1.957	1.981	1.919
Be ²⁺	3.000	3.000	3.000	3.000	3.000	3.000	3.000
Mg ²⁺	0.003	0.009	0.005	0.003	0.003	0.004	0.007
Mn ²⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fe ²⁺	0.031	0.044	0.050	0.038	0.029	0.033	0.053
Li ⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Na ⁺	0.025	0.041	0.034	0.027	0.025	0.032	0.040
K ⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cs ⁺	0.001	0.002	0.000	0.002	0.000	0.002	0.000
H ₂ O	0.172	0.186	0.180	0.174	0.172	0.178	0.186
Cation sum	11.027	11.045	11.044	11.035	11.023	11.039	11.040

Appendix D.4 (contd.): Electron microprobe analyses of beryl.

Sample site		12-TOURMUS-S01			
Point	246be-2	247be-1	247be-2	248be-1	248be-2
Description	white primary beryl	white primary beryl	white primary beryl	white primary beryl	white primary beryl
SiO ₂	66.03	66.39	66.58	65.68	65.97
Al ₂ O ₃	18.25	18.30	18.34	18.27	18.42
BeO [¶]	13.76 [*]	13.8 [*]	13.84 [*]	12.94	13.01
MgO	0.04	0.03	0.02	--	--
MnO	--	--	--	--	--
FeO	0.75	0.49	0.49	0.40	0.40
Li ₂ O [*]	--	--	--	0.40	0.40
Na ₂ O	0.27	0.16	0.20	0.25	0.25
K ₂ O	--	--	--	--	--
Cs ₂ O	--	--	--	0.10	0.10
H ₂ O [§]	1.07	0.97	1.01	1.05	1.05
Total	100.17	100.14	100.48	99.09	99.60
Si ⁴⁺	5.993	6.008	6.008	6.027	6.023
Al ³⁺	1.952	1.952	1.951	1.976	1.982
Be ²⁺	3.000	3.000	3.000	2.852	2.853
Mg ²⁺	0.005	0.004	0.003	0.000	0.000
Mn ²⁺	0.000	0.000	0.000	0.000	0.000
Fe ²⁺	0.057	0.037	0.037	0.031	0.031
Li ⁺	0.000	0.000	0.000	0.148	0.147
Na ⁺	0.048	0.028	0.035	0.044	0.044
K ⁺	0.000	0.000	0.000	0.000	0.000
Cs ⁺	0.000	0.000	0.000	0.004	0.004
H ₂ O	0.192	0.175	0.181	0.189	0.189
Cation sum	11.055	11.030	11.034	11.043	11.044

Appendix D.5: Electron microprobe analyses of bertrandite

Locality	12-SIMPLE9-S05	
Point	24-1-4	24-1-5
SiO ₂	49.34	49.68
Al ₂ O ₃	0.08	0.38
CaO	0.26	0.69
BeO *	41.25	41.95
H ₂ O *	7.43	7.55
TOTAL	98.36	100.25
Si ⁴⁺	1.992	1.972
Al ³⁺	0.004	0.018
Ca ²⁺	0.011	0.029
Be ²⁺	4	4
OH ⁻	2	2
O	9	9

* Determined by stoichiometry

-Formula contents on a basis of 9 anions

Appendix D.6: Electron microprobe analyses of chrysoberyl.

Locality	12-GARMUS-S01			
Point	GM1-2	GM1-3	GM1-4	GM1-5
TiO ₂	0.04	0.26	0.00	0.08
Al ₂ O ₃	78.66	78.06	79.38	77.90
FeO	1.57	1.41	1.12	1.92
BeO *	19.49	19.37	19.60	19.35
Total	99.76	99.1	100.1	99.25
Ti ⁴⁺	0.001	0.004	0.000	0.001
Al ³⁺	1.980	1.977	1.987	1.975
Fe ²⁺	0.028	0.025	0.020	0.035
Be ²⁺	1	1	1	1
O	4	4	4	4

* Determined by stoichiometry

-Formula contents on a basis of 4 anions

Appendix D.7: Electron microprobe analyses of columbite-group minerals (Clb), rutile (Rt), cassiterite (cst), hübnerite (Hub), and qitianlingite (Qit)

Mineral	Clb	Clb	Clb	Clb	Clb	Clb	Clb	Clb	Clb
Site	BERYL-S01	BERYL-S01	BERYL-S02	BERYL-S02	BERYL-S02	BERYL-S01	BERYL-S01	BERYL-S01	BERYL-S01
Point	222c-1	222c-2	224c-1	224c-2	225c-2	219c-1	219c-2	221c-1	221c-2
WO ₃	15.64	13.69	17.53	7.65	12.43	2.58	1.73	8.05	7.20
Nb ₂ O ₅	39.04	39.77	53.54	60.83	55.54	51.71	55.37	42.98	43.83
Ta ₂ O ₅	22.82	23.64	6.39	9.78	6.75	20.09	22.63	26.57	27.57
TiO ₂	1.08	1.23	1.13	1.16	1.13	1.63	1.40	1.59	1.43
ZrO ₂	0.35	0.33	0.23	0.15	0.33	0.94	0.15	0.44	0.37
SnO ₂	1.16	0.91	0.29	0.28	0.59	0.10	0.08	0.98	0.73
UO ₂	0.03	0.01	0.00	0.00	0.02	0.07	0.07	0.11	0.00
Al ₂ O ₃	0.03	0.06	0.00	0.02	0.03	0.02	0.01	0.01	0.00
Sc ₂ O ₃	0.00	0.00	0.35	0.23	0.34	0.00	0.02	0.01	0.00
Bi ₂ O ₃	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MgO	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.07	0.07
CaO	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.01	0.03
Fe ₂ O ₃ *	1.43	0.93	0.94	0.20	2.05	2.63	1.29	0.97	0.88
FeO*	9.27	9.32	9.60	9.72	9.03	9.84	8.63	8.64	8.10
Mn ₂ O ₃ *	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO*	9.02	8.91	10.58	10.31	9.64	6.87	9.81	9.09	9.77
Total	99.75	98.72	100.50	100.32	97.71	96.25	101.07	99.42	99.90
W	0.265	0.234	0.275	0.118	0.197	0.042	0.027	0.135	0.120
Nb	1.154	1.184	1.464	1.635	1.536	1.481	1.522	1.257	1.276
Ta	0.406	0.423	0.105	0.158	0.112	0.346	0.374	0.468	0.483
Ti	0.053	0.061	0.051	0.052	0.052	0.078	0.064	0.077	0.069
Zr	0.011	0.011	0.007	0.004	0.010	0.029	0.004	0.014	0.012
Sn	0.030	0.024	0.007	0.007	0.014	0.003	0.002	0.025	0.019
U ⁴⁺	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.000
Al	0.002	0.005	0.000	0.001	0.002	0.001	0.001	0.001	0.000
Sc	0.000	0.000	0.018	0.012	0.018	0.000	0.001	0.001	0.000
Bi	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mg	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.007	0.007
Ca	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.001	0.002
Fe ³⁺	0.070	0.046	0.043	0.009	0.095	0.125	0.059	0.047	0.043
Fe ²⁺	0.507	0.513	0.486	0.483	0.462	0.522	0.439	0.468	0.437
Mn ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mn ²⁺	0.499	0.497	0.542	0.519	0.499	0.369	0.505	0.498	0.533
O	6	6	6	6	6	6	6	6	6
Sum R ^{4,5,6+}	1.919	1.937	1.910	1.974	1.922	1.980	1.994	1.978	1.979
Sum R ^{1,2,3+}	1.081	1.063	1.090	1.026	1.078	1.020	1.006	1.022	1.021
Mn/(Fe+Mn)	0.464	0.471	0.506	0.513	0.473	0.363	0.504	0.492	0.526
Ta/(Nb+Ta)	0.260	0.263	0.067	0.088	0.068	0.189	0.197	0.271	0.275

*Note: data were recalculated on the basis of fully occupied cation and anion sites and electroneutral formula.

Appendix D.7 (contd.): Electron microprobe analyses of columbite-group minerals (Clb), rutile (Rt), cassiterite (cst), hübnerite (Hub), and qitianlingite (Qit)

Mineral	Clb	Clb	Clb	Clb	Clb	Clb	Clb	Clb	Clb
Site	LI-S01	LI-S01	LI-S01	LI-S01	GARPHOS-S01-1	GARPHOS-S01-1	GARPHOS-S01-1	GARPHOS-S01-1	GARPHOS-S01-1
Point	231c-1	231c-2	231ta-1	231ta-2	GPc-1	GPc-2	GPc-3	GPc-4	GPc-5
WO ₃	2.81	2.57	1.13	1.52	7.24	7.14	3.73	7.89	15.99
Nb ₂ O ₅	46.70	46.15	15.31	15.69	58.34	57.52	57.14	59.07	51.65
Ta ₂ O ₅	29.71	30.54	64.66	64.32	9.66	12.36	15.36	9.60	8.51
TiO ₂	2.02	1.86	2.11	2.15	3.50	3.13	2.80	3.72	2.52
ZrO ₂	0.32	0.31	0.40	0.50	0.58	0.58	0.29	0.46	0.47
SnO ₂	0.00	0.00	0.02	0.02	0.23	0.30	0.26	0.28	0.31
UO ₂	0.39	0.29	0.50	0.48	0.33	0.22	0.29	0.41	0.33
Al ₂ O ₃	0.01	0.04	0.02	0.02	0.00	0.15	0.02	0.02	0.61
Sc ₂ O ₃	0.03	0.00	0.00	0.00	0.03	0.46	0.37	0.04	0.16
Bi ₂ O ₃	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.10
MgO	0.09	0.09	0.09	0.08	0.00	0.01	0.00	0.01	0.02
CaO	0.01	0.01	0.01	0.01	0.02	0.00	0.00	0.00	0.02
Fe ₂ O ₃ *	0.80	1.45	1.29	1.39	1.46	1.42	1.39	1.20	1.76
FeO*	5.45	4.99	4.23	4.15	3.05	1.86	0.55	3.56	0.75
Mn ₂ O ₃ *	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO*	12.16	12.24	9.87	10.09	15.63	16.69	17.49	15.62	17.94
Total	100.42	100.39	99.52	100.33	99.93	101.70	99.55	101.76	100.96
W	0.046	0.042	0.022	0.029	0.111	0.108	0.058	0.118	0.248
Nb	1.338	1.324	0.522	0.530	1.555	1.518	1.548	1.548	1.395
Ta	0.512	0.527	1.327	1.306	0.155	0.196	0.250	0.151	0.138
Ti	0.096	0.089	0.120	0.121	0.155	0.137	0.126	0.162	0.113
Zr	0.010	0.010	0.015	0.018	0.017	0.017	0.008	0.013	0.014
Sn	0.000	0.000	0.001	0.001	0.005	0.007	0.006	0.006	0.007
U ⁴⁺	0.006	0.004	0.008	0.008	0.004	0.003	0.004	0.005	0.004
Al	0.001	0.003	0.002	0.002	0.000	0.010	0.001	0.001	0.043
Sc	0.002	0.000	0.000	0.000	0.002	0.023	0.019	0.002	0.008
Bi	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.002
Mg	0.009	0.009	0.010	0.009	0.000	0.001	0.000	0.001	0.002
Ca	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.001
Fe ³⁺	0.038	0.069	0.074	0.078	0.065	0.062	0.062	0.052	0.079
Fe ²⁺	0.289	0.265	0.267	0.259	0.150	0.091	0.028	0.172	0.037
Mn ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mn ²⁺	0.653	0.658	0.631	0.638	0.780	0.825	0.888	0.767	0.908
O	6	6	6	6	6	6	6	6	6
Sum R ^{4,5,6+}	2.008	1.996	2.015	2.012	2.002	1.987	2.001	2.004	1.920
Sum R ^{1,2,3+}	0.992	1.004	0.985	0.988	0.998	1.013	0.999	0.996	1.080
Mn/(Fe+Mn)	0.666	0.663	0.649	0.654	0.784	0.843	0.908	0.773	0.886
Ta/(Nb+Ta)	0.277	0.285	0.718	0.711	0.091	0.114	0.139	0.089	0.090

Appendix D.7 (contd.): Electron microprobe analyses of columbite-group minerals (Clb), rutile (Rt), cassiterite (cst), hübnerite (Hub), and qitianlingite (Qit)

Mineral	Clb	Clb	Clb	Clb	Clb	Clb	Clb	Clb	Clb
Site	GARPHOS-S01-1	GARPHOS-S01-1	GARPHOS-S01-1	GARPHOS-S01-1	GARPHOS-S01-1	GARPHOS-S04	GARPHOS-S04	GARPHOS-S04	GARPHOS-S04
Point	GPc-6	GPc-7	GPc-8	GPc-9	GPc-10	198c-1	198c-2	198c-3	198c-4
WO ₃	2.68	4.62	2.46	2.85	3.04	17.01	9.98	14.47	11.10
Nb ₂ O ₅	47.39	54.16	37.37	47.50	36.96	47.24	52.01	48.72	50.98
Ta ₂ O ₅	26.05	15.11	40.02	26.29	37.31	13.17	16.43	14.28	16.12
TiO ₂	4.42	4.85	1.77	4.55	4.58	1.30	1.07	1.14	1.27
ZrO ₂	0.44	0.63	0.18	0.36	0.41	0.35	0.10	0.15	0.14
SnO ₂	0.52	0.67	0.19	0.48	0.65	0.03	0.01	0.00	0.10
UO ₂	0.07	1.25	0.24	0.03	0.43	0.19	0.11	0.16	0.09
Al ₂ O ₃	0.01	0.03	0.02	0.02	0.01	0.01	0.00	0.00	0.02
Sc ₂ O ₃	1.82	0.23	0.13	2.06	1.76	0.00	0.00	0.00	0.00
Bi ₂ O ₃	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MgO	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.01
CaO	0.01	0.00	0.01	0.01	0.00	0.00	0.01	0.00	0.01
Fe ₂ O ₃ *	0.74	1.34	0.54	0.41	0.16	1.05	0.84	0.27	0.62
FeO*	0.05	0.47	0.00	0.00	0.00	4.79	4.41	5.18	4.80
Mn ₂ O ₃ *	0.00	0.00	0.01	0.33	0.33	0.00	0.00	0.00	0.00
MnO*	16.32	17.09	16.81	16.35	15.65	14.71	14.80	14.49	14.53
Total	100.44	100.32	99.70	101.17	101.24	99.75	99.70	98.83	99.73
W	0.043	0.071	0.043	0.045	0.050	0.277	0.161	0.237	0.179
Nb	1.312	1.457	1.132	1.304	1.071	1.340	1.459	1.393	1.434
Ta	0.434	0.245	0.729	0.434	0.650	0.225	0.277	0.246	0.273
Ti	0.204	0.217	0.089	0.208	0.221	0.061	0.050	0.054	0.059
Zr	0.013	0.018	0.006	0.011	0.013	0.011	0.003	0.005	0.004
Sn	0.013	0.016	0.005	0.012	0.017	0.001	0.000	0.000	0.002
U ⁴⁺	0.001	0.017	0.004	0.000	0.006	0.003	0.002	0.002	0.001
Al	0.001	0.002	0.002	0.001	0.001	0.001	0.000	0.000	0.001
Sc	0.097	0.012	0.008	0.109	0.098	0.000	0.000	0.000	0.000
Bi	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mg	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.000	0.001
Ca	0.001	0.000	0.001	0.001	0.000	0.000	0.001	0.000	0.001
Fe ³⁺	0.034	0.060	0.027	0.019	0.008	0.050	0.039	0.013	0.029
Fe ²⁺	0.002	0.024	0.000	0.000	0.000	0.251	0.229	0.274	0.250
Mn ³⁺	0.000	0.000	0.001	0.015	0.016	0.000	0.000	0.000	0.000
Mn ²⁺	0.846	0.861	0.954	0.841	0.850	0.782	0.778	0.776	0.766
O	6	6	6	6	6	6	6	6	6
Sum R ^{4,5,6+}	2.019	2.041	2.008	2.014	2.028	1.916	1.952	1.937	1.953
Sum R ^{1,2,3+}	0.981	0.959	0.992	0.986	0.972	1.084	1.048	1.063	1.047
Mn/(Fe+Mn)	0.959	0.912	0.972	0.979	0.991	0.722	0.744	0.730	0.733
Ta/(Nb+Ta)	0.248	0.144	0.392	0.250	0.378	0.144	0.160	0.150	0.160

Appendix D.7 (contd.): Electron microprobe analyses of columbite-group minerals (Clb), rutile (Rt), cassiterite (cst), hübnerite (Hub), and qitianlingite (Qit)

Mineral	Clb	Clb	Clb	Clb	Rt	Rt	Rt	Rt	Rt
Site	GARPHOS-S04	GARPHOS-S04	GARPHOS-S04	GARPHOS-S04	GRANITE-S05-1	GRANITE-S05-1	GRANITE-S05-1	GRANITE-S05-1	GRANITE-S05-1
Point	195c-1	195c-2	195c-3	196c-1	5GNr-1	5GNr-2	5GNr-3	5GNr-4	5GNr-5
WO ₃	0.90	3.81	4.99	1.78	0.07	0.35	1.73	0.55	0.81
Nb ₂ O ₅	57.20	59.03	56.70	62.52	1.15	1.21	1.93	1.84	2.12
Ta ₂ O ₅	5.89	15.98	16.60	14.20	0.00	0.00	0.29	0.32	0.26
TiO ₂	14.12	1.16	1.20	1.64	94.68	94.73	91.96	94.07	93.78
ZrO ₂	0.81	0.09	0.09	0.31	0.06	0.03	0.01	0.00	0.05
SnO ₂	0.46	0.00	0.05	0.06	0.27	0.21	0.68	0.49	0.79
UO ₂	0.19	0.06	0.00	0.02	0.00	0.00	0.01	0.00	0.00
Al ₂ O ₃	0.01	0.00	0.02	0.02	0.22	0.18	0.11	0.10	0.07
Sc ₂ O ₃	0.00	0.00	0.01	0.00	0.39	0.31	0.01	0.01	0.01
Bi ₂ O ₃	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MgO	0.00	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.00
CaO	0.13	0.01	0.01	0.03	0.14	0.06	0.02	0.03	0.02
Fe ₂ O ₃ *	6.03	0.64	1.34	3.09	0.40	0.51	2.12	1.51	1.68
FeO*	2.37	3.65	2.94	4.32	0.00	0.00	0.02	0.00	0.03
Mn ₂ O ₃ *	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.03	0.00
MnO*	11.30	15.58	15.78	13.82	0.00	0.00	0.02	0.00	0.00
Total	98.80	99.95	99.60	101.50	97.38	97.55	98.70	98.80	99.45
W	0.013	0.060	0.079	0.027	0.000	0.001	0.006	0.002	0.003
Nb	1.406	1.611	1.560	1.640	0.007	0.007	0.012	0.011	0.013
Ta	0.087	0.262	0.275	0.224	0.000	0.000	0.001	0.001	0.001
Ti	0.578	0.053	0.055	0.072	0.976	0.977	0.952	0.965	0.959
Zr	0.021	0.003	0.003	0.009	0.000	0.000	0.000	0.000	0.000
Sn	0.010	0.000	0.001	0.001	0.001	0.001	0.004	0.003	0.004
U ⁴⁺	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Al	0.001	0.000	0.001	0.001	0.004	0.003	0.002	0.002	0.001
Sc	0.000	0.000	0.001	0.000	0.005	0.004	0.000	0.000	0.000
Bi	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mg	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Ca	0.008	0.001	0.001	0.002	0.002	0.001	0.000	0.000	0.000
Fe ³⁺	0.247	0.029	0.061	0.135	0.004	0.005	0.022	0.016	0.017
Fe ²⁺	0.108	0.184	0.150	0.210	0.000	0.000	0.000	0.000	0.000
Mn ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mn ²⁺	0.520	0.797	0.813	0.679	0.000	0.000	0.000	0.000	0.000
O	6	6	6	6	2	2	2	2	2
Sum R ^{4,5,6+}	2.117	1.989	1.972	1.973	0.985	0.987	0.975	0.982	0.981
Sum R ^{1,2,3+}	0.883	1.011	1.028	1.027	0.015	0.013	0.025	0.018	0.019
Mn/(Fe+Mn)	0.595	0.789	0.794	0.663	0.078	0.000	0.010	0.022	0.000
Ta/(Nb+Ta)	0.058	0.140	0.150	0.120	0.000	0.000	0.083	0.095	0.069

Appendix D.7 (contd.): Electron microprobe analyses of columbite-group minerals (Clb), rutile (Rt), cassiterite (cst), hübnerite (Hub), and qitianlingite (Qit)

Mineral	Rt	Rt	Cst	Cst	Cst	Cst	Cst	Hub	Hub
Site	GRANITE-S05-1	GARPHOS-S04	BERYL-S01	BERYL-S01	BERYL-S01	BERYL-S01	BERYL-S01	LI-S01-5	LI-S01-5
Point	5GNr-6	195r-1	221cs-2	222cs-1	222cs-2	221cs-1	221cs-2	5Lih-1	5Lih-2
WO ₃	2.03	0.01	0.01	0.11	0.01	0.00	0.00	78.64	75.61
Nb ₂ O ₅	2.36	19.14	0.23	1.37	0.67	0.68	0.81	0.85	1.19
Ta ₂ O ₅	0.52	3.11	1.50	4.99	2.41	2.68	2.49	0.00	0.00
TiO ₂	90.86	65.01	0.13	0.29	0.16	0.17	0.20	0.01	0.00
ZrO ₂	0.01	0.20	0.00	0.16	0.16	0.06	0.00	0.32	0.36
SnO ₂	0.70	0.09	97.82	91.82	95.64	95.59	95.12	0.06	0.14
UO ₂	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Al ₂ O ₃	0.07	0.06	0.00	0.03	0.00	0.00	0.12	0.00	0.00
Sc ₂ O ₃	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Bi ₂ O ₃	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
MgO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
CaO	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.02
Fe ₂ O ₃ *	2.21	11.08	0.25	0.39	0.21	0.29	0.38	0.00	0.90
FeO *	0.29	0.00	0.16	0.91	0.43	0.42	0.35	0.68	0.17
Mn ₂ O ₃ *	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO *	0.00	0.59	0.04	0.11	0.05	0.07	0.02	23.47	22.84
Total	98.85	98.26	100.11	100.14	99.72	99.93	99.45	104.05	101.19
W	0.007	0.000	0.000	0.001	0.000	0.000	0.000	0.984	0.966
Nb	0.015	0.128	0.003	0.015	0.008	0.008	0.009	0.019	0.027
Ta	0.002	0.013	0.010	0.034	0.016	0.018	0.017	0.000	0.000
Ti	0.944	0.724	0.002	0.005	0.003	0.003	0.004	0.000	0.000
Zr	0.000	0.001	0.000	0.002	0.002	0.001	0.000	0.008	0.009
Sn	0.004	0.001	0.976	0.913	0.957	0.954	0.952	0.001	0.003
U ⁴⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Al	0.001	0.001	0.000	0.001	0.000	0.000	0.004	0.000	0.000
Sc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Bi	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mg	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
Ca	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
Fe ³⁺	0.023	0.123	0.005	0.007	0.004	0.006	0.007	0.000	0.034
Fe ²⁺	0.003	0.000	0.003	0.019	0.009	0.009	0.007	0.027	0.007
Mn ³⁺	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mn ²⁺	0.000	0.007	0.001	0.002	0.001	0.001	0.000	0.960	0.954
O	2	2	2	2	2	2	2	4	4
Sum R ^{4,5,6+}	0.972	0.867	0.991	0.971	0.986	0.984	0.982	1.012	1.004
Sum R ^{1,2,3+}	0.028	0.133	0.009	0.029	0.014	0.016	0.018	0.988	0.996
Mn/(Fe+Mn)	0.000	0.062	0.096	0.081	0.076	0.094	0.029	0.972	0.959
Ta/(Nb+Ta)	0.117	0.089	0.797	0.687	0.684	0.703	0.649	0.000	0.000

Appendix D.7 (contd.): Electron microprobe analyses of columbite-group minerals (Clb), rutile (Rt), cassiterite (cst), hübnerite (Hub), and qitianlingite (Qit)

Mineral	Hub	Hub	Qit	Qit	Qit	Qit	Qit	Qit	Qit
Site	LI-S01-5	GARPHOS-S04	LI-S01-5	LI-S01-5	LI-S01-5	LI-S01-5	LI-S01-5	LI-S01-5	LI-S01-5
Point	5Llc-3	195w-2	5Llc-1	5Llc-2	5Llc-4	5Llc-5	5Llc-6	5Llc-7	5Llc-8
WO ₃	70.86	67.85	31.06	36.52	35.71	42.72	42.92	42.59	41.00
Nb ₂ O ₅	4.58	6.59	42.84	31.10	38.27	16.47	17.64	16.36	17.65
Ta ₂ O ₅	0.18	1.23	3.93	2.75	3.49	1.47	1.61	1.35	1.49
TiO ₂	0.16	0.64	1.46	1.56	1.15	1.06	1.10	0.95	1.13
ZrO ₂	0.63	0.42	0.36	1.12	0.55	1.62	1.85	1.74	1.76
SnO ₂	0.29	0.18	0.15	0.25	0.34	0.33	0.32	0.33	0.34
UO ₂	0.00	0.01	0.08	0.51	0.13	0.67	0.65	0.52	0.63
Al ₂ O ₃	0.33	0.01	0.00	0.25	0.03	2.38	2.38	1.80	1.68
Sc ₂ O ₃	0.03	0.00	0.03	0.05	0.04	0.06	0.05	0.06	0.05
Bi ₂ O ₃	0.33	0.00	0.00	0.76	0.00	4.51	4.57	3.52	3.53
MgO	0.00	0.00	0.00	0.01	0.00	0.08	0.09	0.10	0.12
CaO	0.03	0.06	0.01	0.13	0.00	0.45	0.48	0.65	0.55
Fe ₂ O ₃ *	4.13	1.83	0.77	5.72	1.93	10.32	10.52	10.65	11.04
FeO*	0.78	5.96	0.86	1.97	1.84	0.00	0.00	0.00	0.00
Mn ₂ O ₃ *	0.00	0.00	0.00	0.00	0.00	6.00	6.01	9.42	7.58
MnO*	19.99	15.94	20.35	14.93	18.98	7.34	7.58	5.83	6.55
Total	101.91	100.53	101.82	97.06	102.27	93.84	96.11	93.85	93.22
W	0.869	0.846	0.831	1.040	0.965	1.259	1.232	1.236	1.199
Nb	0.098	0.143	2.000	1.545	1.804	0.847	0.884	0.828	0.900
Ta	0.002	0.016	0.110	0.082	0.099	0.045	0.049	0.041	0.046
Ti	0.006	0.023	0.113	0.129	0.090	0.091	0.092	0.080	0.096
Zr	0.015	0.010	0.018	0.060	0.028	0.090	0.100	0.095	0.097
Sn	0.005	0.003	0.006	0.011	0.014	0.015	0.014	0.015	0.015
U ⁴⁺	0.000	0.000	0.002	0.012	0.003	0.017	0.016	0.013	0.016
Al	0.018	0.001	0.000	0.032	0.004	0.319	0.311	0.237	0.223
Sc	0.001	0.000	0.003	0.005	0.004	0.006	0.005	0.006	0.005
Bi	0.004	0.000	0.000	0.022	0.000	0.132	0.131	0.102	0.103
Mg	0.000	0.000	0.000	0.002	0.000	0.014	0.015	0.017	0.020
Ca	0.002	0.003	0.001	0.015	0.000	0.055	0.057	0.078	0.066
Fe ³⁺	0.147	0.066	0.060	0.473	0.151	0.884	0.877	0.897	0.937
Fe ²⁺	0.031	0.240	0.074	0.181	0.161	0.000	0.000	0.000	0.000
Mn ³⁺	0.000	0.000	0.000	0.000	0.000	0.520	0.507	0.803	0.651
Mn ²⁺	0.801	0.649	1.780	1.390	1.677	0.707	0.711	0.553	0.626
O	4	4	10	10	10	10	10	10	10
Sum R ^{4,5,6+}	0.995	1.041	3.082	2.880	3.004	2.364	2.386	2.307	2.369
Sum R ^{1,2,3+}	1.005	0.959	1.918	2.120	1.996	2.636	2.614	2.693	2.631
Mn/(Fe+Mn)	0.818	0.680	0.930	0.680	0.843	0.581	0.581	0.602	0.577
Ta/(Nb+Ta)	0.023	0.101	0.052	0.051	0.052	0.051	0.052	0.047	0.048

Appendix D.7 (contd.): Electron microprobe analyses of columbite-group minerals (Clb), rutile (Rt), cassiterite (cst), hübnerite (Hub), and qitianlingite (Qit)

Mineral	Qit	Qit	Qit	Qit	Qit	Qit	Qit
Site	LI-S01-5	LI-S01-5	LI-S01-5	LI-S01-5	LI-S01-5	BERYL-S02	GARPHOS-S04
Point	5Llc-9	5Llc-10	5Llc-11	5Llc-12	5Llc-13	225c-1	195w-1
WO ₃	39.09	39.74	43.31	41.96	30.05	32.84	38.35
Nb ₂ O ₅	33.22	31.32	19.15	23.19	33.06	37.16	34.00
Ta ₂ O ₅	2.80	2.68	1.63	1.93	1.55	4.80	4.40
TiO ₂	1.63	1.49	1.06	1.21	0.91	1.74	1.30
ZrO ₂	1.27	1.21	1.80	1.61	0.19	1.24	0.23
SnO ₂	0.26	0.21	0.42	0.35	0.09	0.29	0.18
UO ₂	0.53	0.44	0.42	0.37	0.06	0.27	0.00
Al ₂ O ₃	0.07	0.21	1.79	1.34	5.80	0.02	0.00
Sc ₂ O ₃	0.04	0.04	0.07	0.07	0.02	0.40	0.00
Bi ₂ O ₃	0.47	0.52	3.29	2.65	0.00	0.00	0.00
MgO	0.01	0.02	0.12	0.09	0.00	0.01	0.00
CaO	0.05	0.08	0.42	0.36	0.06	0.01	0.17
Fe ₂ O ₃ *	2.35	3.65	8.92	9.36	2.85	1.95	1.07
FeO*	4.47	3.20	0.00	0.00	0.00	9.94	5.87
Mn ₂ O ₃ *	0.00	0.00	4.37	2.19	10.15	0.00	0.00
MnO*	15.60	15.78	10.17	12.21	8.32	9.80	15.03
Total	101.62	100.23	95.61	97.73	91.79	100.28	100.49
W	1.078	1.110	1.259	1.190	0.814	0.902	1.073
Nb	1.598	1.526	0.971	1.147	1.563	1.780	1.660
Ta	0.081	0.079	0.050	0.057	0.044	0.138	0.129
Ti	0.130	0.121	0.089	0.100	0.072	0.139	0.106
Zr	0.066	0.064	0.098	0.086	0.010	0.064	0.012
Sn	0.011	0.009	0.019	0.015	0.004	0.012	0.008
U ⁴⁺	0.013	0.011	0.010	0.009	0.001	0.006	0.000
Al	0.009	0.027	0.237	0.173	0.715	0.002	0.000
Sc	0.004	0.004	0.007	0.007	0.002	0.037	0.000
Bi	0.013	0.014	0.095	0.075	0.000	0.000	0.000
Mg	0.002	0.003	0.020	0.015	0.000	0.002	0.000
Ca	0.006	0.009	0.050	0.042	0.007	0.001	0.020
Fe ³⁺	0.188	0.296	0.753	0.770	0.224	0.156	0.087
Fe ²⁺	0.397	0.289	0.000	0.000	0.000	0.881	0.530
Mn ³⁺	0.000	0.000	0.374	0.183	0.808	0.000	0.000
Mn ²⁺	1.406	1.440	0.966	1.132	0.737	0.880	1.375
O	10	10	10	10	10	10	10
Sum R ^{4,5,6+}	2.976	2.918	2.497	2.604	2.508	3.042	2.988
Sum R ^{1,2,3+}	2.024	2.082	2.503	2.396	2.492	1.958	2.012
Mn/(Fe+Mn)	0.706	0.711	0.640	0.630	0.873	0.459	0.690
Ta/(Nb+Ta)	0.048	0.049	0.049	0.048	0.027	0.072	0.072

Appendix D.8: Electron microprobe analyses of monazite (Mnz) and xenotime (Xnt).

Mineral	Mnz	Mnz	Mnz	Mnz	Mnz	Mnz	Mnz	Mnz	Xnt	Xnt	Xnt	Xnt	Xnt	Xnt	Xnt
Comment	overlap with biotite														
Sample	GRANITE-S09	GARPHOS-S04	GARPHOS-S04	GARPHOS-S04	GARPHOS-S04	GRANITE-S05-1	SIMPLE9-S04-4	SIMPLE9-S04-4	GRANITE-S09	GRANITE-S05-1	GRANITE-S05-1	SIMPLE9-S04-4	SIMPLE9-S04-4	SIMPLE9-S04-4	SIMPLE9-S04-4
Point	21mz-1	198mz-1	198mz-2	198mz-3	198mz-4	5GNmz-1	4S94x-5	4S94x-6	21x-1	5GNx-1	5GNx-2	4S94x-1	4S94x-2	4S94x-3	4S94x-4
P ₂ O ₅ (wt.%)	30.95	30.25	30.67	30.47	30.49	27.50	29.53	29.37	27.75	23.28	33.18	35.38	33.53	35.10	35.83
SiO ₂	0.15	0.37	0.17	0.21	0.19	9.92	1.04	1.13			2.20	0.72	1.47	0.79	0.56
TiO ₂	0.00	0.00	0.00	0.00	0.00	2.35	0.00	0.00	0.00	1.81	1.26	0.00	0.00	0.00	0.00
SnO ₂	0.00	0.00	0.00	0.00	0.00	1.32	0.00	0.02	0.00	0.11	0.00	0.00	0.00	0.00	0.00
ThO ₂	2.20	14.87	12.02	15.76	14.99	0.00	5.45	5.05	0.15	0.04	0.00	0.15	0.45	0.20	0.08
UO ₂	0.63	6.97	4.25	6.51	5.34	0.44	0.11	0.16	3.45	0.57	0.29	3.46	7.38	4.65	3.82
Al ₂ O ₃	0.00	0.00	0.00	0.00	0.00	0.55	0.00	0.01			0.00	0.00	0.00	0.00	0.00
Sc ₂ O ₃	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.03	0.27	0.13	0.04	0.03	0.03	0.03
As ₂ O ₃	0.00	0.04	0.05	0.01	0.02	0.08	0.13	0.17	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Y ₂ O ₃	1.69	0.07	0.00	0.08	0.06	1.88	1.15	0.70	33.66	29.18	40.65	40.06	38.53	40.19	40.94
La ₂ O ₃	16.98	7.14	7.98	6.89	7.23	3.32	14.24	14.34	0.03	0.04	0.04	0.00	0.05	0.00	0.01
Ce ₂ O ₃	31.74	21.07	24.66	20.77	22.53	22.05	30.75	31.34	0.13	0.06	0.19	0.12	0.09	0.03	0.03
Pr ₂ O ₃	3.09	2.26	2.99	2.49	2.50	4.42	3.33	3.40	0.00	0.05	0.00	0.00	0.00	0.23	0.00
Nd ₂ O ₃	6.79	6.23	7.25	6.12	6.61	21.77	11.45	12.00	0.14	0.11	0.35	0.43	0.30	0.30	0.53
SmO	2.20	3.81	4.18	3.72	3.60	6.04	2.52	2.23	0.58	0.30	0.71	0.78	0.75	0.82	0.64
EuO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.66	0.00	0.00	0.00	0.00	0.00	0.00
Gd ₂ O ₃	0.51	0.62	0.52	0.58	0.73	1.94	0.84	0.99	3.38	2.14	4.36	4.00	4.14	3.90	4.41
Tb ₂ O ₃	0.00	0.00	0.00	0.00	0.00	0.19	0.22	0.11	0.24	0.38	0.65	0.67	0.58	0.60	0.69
Dy ₂ O ₃	0.33	0.01	0.00	0.08	0.00	0.38	0.31	0.35	4.39	2.71	5.54	5.22	4.91	4.70	5.22
Ho ₂ O ₃	0.00	0.00	0.33	0.00	0.18	0.00	0.23	0.00	0.00	0.24	0.82	0.20	0.52	0.67	0.49
Er ₂ O ₃	0.05	0.00	0.03	0.00	0.00	0.12	0.06	0.00	2.46	1.92	4.12	3.76	3.83	4.06	3.98
Tm ₂ O ₃	0.13	0.62	0.58	0.51	0.56	0.68	0.31	0.30	0.00	0.00	0.41	0.41	0.43	0.34	0.35
Yb ₂ O ₃	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	5.91	3.16	7.37	7.53	6.69	7.23	7.01
Bi ₂ O ₃	1.66	1.34	1.55	1.19	1.44	1.14	1.51	1.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MgO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.00	0.00	0.00	0.00	0.00
CaO	0.61	4.52	3.44	4.65	4.21	0.48	0.44	0.23	0.61	0.16	0.10	0.28	0.40	0.29	0.27
FeO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.72	0.00	0.00	0.00	0.00	0.00
K ₂ O	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00			0.00	0.00	0.00	0.00	0.00
F	0.52	0.33	0.37	0.34	0.31	0.20	0.29	0.43	0.00	0.00	0.05	0.00	0.02	0.00	0.00
Total	100.22	100.53	101.07	100.39	101.08	106.93	103.93	104.05	96.24	100.09	102.45	103.25	104.14	104.14	104.88
P ⁵⁺ (apfu)	1.017	0.998	1.007	1.005	1.003	0.773	0.957	0.956	0.966	0.944	0.921	0.990	0.951	0.981	0.989
Si ⁴⁺	0.006	0.014	0.007	0.008	0.007	0.329	0.040	0.043	0.000	0.000	0.072	0.024	0.049	0.026	0.018
Ti ⁴⁺	0.000	0.000	0.000	0.000	0.000	0.059	0.000	0.000	0.000	0.065	0.031	0.000	0.000	0.000	0.000
Sn ⁴⁺	0.000	0.000	0.000	0.000	0.000	0.017	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000
Th ⁴⁺	0.019	0.132	0.106	0.140	0.133	0.000	0.047	0.044	0.001	0.000	0.000	0.001	0.003	0.002	0.001
U ⁴⁺	0.005	0.060	0.037	0.056	0.046	0.003	0.001	0.001	0.032	0.006	0.002	0.025	0.055	0.034	0.028
Al ³⁺	0.000	0.000	0.000	0.000	0.000	0.022	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sc ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.011	0.004	0.001	0.001	0.001	0.001
As ³⁺	0.000	0.001	0.001	0.000	0.000	0.002	0.003	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y ³⁺	0.035	0.001	0.000	0.002	0.001	0.033	0.023	0.014	0.737	0.743	0.709	0.705	0.687	0.706	0.711
La ³⁺	0.243	0.103	0.114	0.099	0.104	0.041	0.201	0.203	0.000	0.001	0.000	0.000	0.001	0.000	0.000
Ce ³⁺	0.451	0.301	0.350	0.296	0.320	0.268	0.431	0.441	0.002	0.001	0.002	0.001	0.001	0.000	0.000
Pr ³⁺	0.044	0.032	0.042	0.035	0.035	0.053	0.046	0.048	0.000	0.001	0.000	0.000	0.000	0.003	0.000
Nd ³⁺	0.094	0.087	0.100	0.085	0.092	0.258	0.157	0.165	0.002	0.002	0.004	0.005	0.004	0.004	0.006
Sm ²⁺	0.031	0.054	0.059	0.052	0.051	0.072	0.035	0.031	0.009	0.005	0.008	0.009	0.009	0.010	0.008
Eu ²⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.010	0.000	0.000	0.000	0.000	0.000	0.000
Gd ³⁺	0.007	0.008	0.007	0.007	0.009	0.021	0.011	0.013	0.046	0.034	0.047	0.044	0.046	0.043	0.048
Tb ³⁺	0.000	0.000	0.000	0.000	0.000	0.002	0.003	0.001	0.003	0.006	0.007	0.007	0.006	0.007	0.007
Dy ³⁺	0.004	0.000	0.000	0.001	0.000	0.004	0.004	0.004	0.058	0.042	0.059	0.056	0.053	0.050	0.055
Ho ³⁺	0.000	0.000	0.004	0.000	0.002	0.000	0.003	0.000	0.000	0.004	0.009	0.002	0.006	0.007	0.005
Er ³⁺	0.001	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.032	0.029	0.042	0.039	0.040	0.042	0.041
Tm ³⁺	0.002	0.008	0.007	0.006	0.007	0.007	0.004	0.004	0.000	0.000	0.004	0.004	0.004	0.003	0.004
Yb ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.074	0.046	0.074	0.076	0.068	0.073	0.070
Bi ³⁺	0.017	0.013	0.016	0.012	0.014	0.010	0.015	0.017	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mg ²⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.021	0.000	0.000	0.000	0.000	0.000
Ca ²⁺	0.025	0.189	0.143	0.194	0.175	0.017	0.018	0.009	0.027	0.008	0.004	0.010	0.014	0.010	0.009
Fe ²⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.029	0.000	0.000	0.000	0.000	0.000
K ⁺	0.000	0.000	0.000	0.000	0.000	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
F ⁻	0.064	0.041	0.045	0.042	0.038	0.021	0.035	0.052	0.000	0.000	0.005	0.000	0.002	0.000	0.000

Note: formulae were calculated based on cation sum = 2.

Appendix D.9: Electron microprobe analyses of topaz from the GARPHOS pegmatite.

Sample	GP3-27	GP3-28	GP3-29	GP3-30	GP2-29	GP2-30
SiO ₂	31.69	31.59	31.60	31.68	31.09	31.59
Al ₂ O ₃	55.74	55.50	55.54	55.45	55.44	55.46
FeO	0.02	0.01	0.04	0.00	0.02	0.00
Na ₂ O	0.01	0.02	0.03	0.00	0.00	0.05
F	20.88	19.18	20.19	18.94	18.74	18.69
H ₂ O *	0.00	0.58	0.11	0.70	0.72	0.81
O=F	-8.79	-8.08	-8.50	-7.98	-7.89	-7.87
Total	99.55	98.8	99.01	98.79	98.12	98.73
Si ⁴⁺	0.975	0.979	0.979	0.982	0.970	0.980
Al ³⁺	2.020	2.027	2.027	2.025	2.039	2.027
Fe ²⁺	0.001	0.000	0.001	0.000	0.001	0.000
Na ⁺	0.001	0.001	0.002	0.000	0.000	0.003
F ⁻	2.031	1.880	1.978	1.856	1.850	1.833
OH ⁻	0.000	0.120	0.023	0.144	0.150	0.168
O	3.969	4	4	4	4	4

*Note: formula calculation on basis of 6 anions and OH=(2-F).

Appendix D.10: Electron microprobe analyses of zircon.

Site	12-BERYL-S01	12-BERYL-S01	12-GARPHOS-S04	12-GARPHOS-S04	12-GRANITE-S04	12-GRANITE-S05	12-GRANITE-S05	12-GRANITE-S05	12-LI-S01-5 (decomposed)	12-LI-S01-5 (decomposed)
Point	254z-1	254z-2	198z-1	198z-2	13z-1	5GNz-1	5GNz-2	5GNz-3	5Llz-1	5Llz-2
SiO ₂ (wt.%)	27.32	29.61	31.86	31.57	31.69	32.00	31.53	30.81	19.26	18.79
TiO ₂	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.08	0.06
ZrO ₂	51.36	53.26	62.58	61.25	63.80	64.52	63.70	61.47	38.04	40.31
HfO ₂	3.18	4.14	5.08	5.70	1.75	2.32	2.10	1.70	2.06	2.61
ThO ₂	0.22	0.12	0.00	0.03	0.00	0.00	0.04	0.00	0.41	0.19
UO ₂	18.37	11.10	0.09	0.18	0.43	0.33	0.87	1.59	6.99	5.59
Al ₂ O ₃	0.04	0.00	0.00	0.02	0.00	0.02	0.01	0.00	6.54	5.22
Sc ₂ O ₃	0.07	0.08	0.04	0.00	0.12	0.15	0.29	0.37	0.12	0.18
Y ₂ O ₃	0.32	0.31	0.01	0.02	0.14	0.17	0.51	1.21	3.39	3.11
La ₂ O ₃	0.00	0.00	0.05	0.09	0.00	0.02	0.00	0.03	0.00	0.00
Ce ₂ O ₃	0.05	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.03	0.11
Pr ₂ O ₃	0.18	0.00	0.00	0.00	0.05	0.10	0.13	0.00	0.05	0.03
Nd ₂ O ₃	0.00	0.02	0.00	0.00	0.00	0.02	0.03	0.03	0.00	0.00
SmO	0.08	0.17	0.17	0.09	0.00	0.00	0.00	0.12	0.02	0.14
EuO	0.00	0.06	0.00	0.00	0.03	0.05	0.00	0.00	0.01	0.09
Gd ₂ O ₃	0.35	0.00	0.00	0.01	0.09	0.00	0.18	0.07	0.34	0.00
Tb ₂ O ₃	0.00	0.09	0.03	0.01	0.00	0.03	0.00	0.00	0.06	0.00
Dy ₂ O ₃	0.10	0.13	0.17	0.05	0.00	0.02	0.17	0.05	0.42	0.30
Ho ₂ O ₃	0.00	0.00	0.00	0.05	0.00	0.11	0.00	0.00	0.04	0.02
Er ₂ O ₃	0.04	0.01	0.10	0.11	0.00	0.08	0.09	0.14	0.17	0.13
Tm ₂ O ₃	0.00	0.07	0.00	0.05	0.01	0.00	0.00	0.00	0.00	0.00
Yb ₂ O ₃	0.02	0.00	0.02	0.02	0.15	0.15	0.40	0.71	0.00	0.00
Bi ₂ O ₃	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	2.19	2.08
MnO	0.11	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.23
FeO	0.10	0.01	0.00	0.01	0.09	0.02	0.05	0.02	1.03	0.98
PbO	0.13	0.00	0.00	0.03	0.09	0.06	0.01	0.09	0.05	0.10
Total	102.04	99.30	100.21	99.32	98.45	100.17	100.11	98.41	81.45	80.27
Si ⁴⁺ (apfu)	0.939	0.991	0.995	0.997	0.994	0.990	0.981	0.978	0.746	0.746
Ti ⁴⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.002
Zr ⁴⁺	0.861	0.869	0.953	0.943	0.975	0.973	0.966	0.952	0.718	0.781
Hf ⁴⁺	0.031	0.040	0.045	0.051	0.016	0.020	0.019	0.015	0.023	0.030
Th ⁴⁺	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.002
U ⁴⁺	0.141	0.083	0.001	0.001	0.003	0.002	0.006	0.011	0.060	0.049
Al ³⁺	0.002	0.000	0.000	0.001	0.000	0.001	0.000	0.000	0.298	0.244
Sc ³⁺	0.002	0.002	0.001	0.000	0.003	0.004	0.008	0.010	0.004	0.006
Y ³⁺	0.006	0.006	0.000	0.000	0.002	0.003	0.008	0.020	0.070	0.066
La ³⁺	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Ce ³⁺	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002
Pr ³⁺	0.002	0.000	0.000	0.000	0.001	0.001	0.001	0.000	0.001	0.000
Nd ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sm ²⁺	0.001	0.002	0.002	0.001	0.000	0.000	0.000	0.001	0.000	0.002
Eu ²⁺	0.000	0.001	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.001
Gd ³⁺	0.004	0.000	0.000	0.000	0.001	0.000	0.002	0.001	0.004	0.000
Tb ³⁺	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000
Dy ³⁺	0.001	0.001	0.002	0.001	0.000	0.000	0.002	0.001	0.005	0.004
Ho ³⁺	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000
Er ³⁺	0.000	0.000	0.001	0.001	0.000	0.001	0.001	0.001	0.002	0.002
Tm ³⁺	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Yb ³⁺	0.000	0.000	0.000	0.000	0.001	0.001	0.004	0.007	0.000	0.000
Bi ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.022	0.021
Mn ²⁺	0.003	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.008
Fe ²⁺	0.003	0.000	0.000	0.000	0.002	0.001	0.001	0.001	0.033	0.033
Pb ²⁺	0.001	0.000	0.000	0.000	0.001	0.000	0.000	0.001	0.001	0.001
Zr/Hf	27.6	22.0	21.0	18.4	62.3	47.5	51.8	61.8	31.5	26.4

Note: formula calculation based on the sum of cations = 2.

Appendix D.10 (contd.): Electron microprobe analyses of zircon.

Site	12-PEGMA-S01 (border zone)	12-SIMPLE9-S04 (border zone)	12-SIMPLE9-S04 (border zone)	12-SIMPLE9-S04 (border zone)	12-SIMPLE9-S04 (border zone)	12-SIMPLE9-S04 (border zone)	12-TOURMUS-S01
Point	22-1	4S94z-1	4S94z-2	4S94z-3	4S94z-4	4S94z-5	201z-1
SiO ₂ (wt.%)	31.26	31.97	32.85	32.31	31.78	32.70	31.60
TiO ₂	0.01	0.00	0.00	0.00	0.00	0.02	0.00
ZrO ₂	66.80	65.23	66.21	65.61	63.64	66.06	61.17
HfO ₂	1.52	1.87	1.69	2.23	2.29	1.67	2.73
ThO ₂	0.00	0.00	0.00	0.00	0.00	0.02	0.00
UO ₂	0.00	0.58	0.05	0.35	0.72	0.02	1.22
Al ₂ O ₃	0.00	0.06	0.01	0.00	0.00	0.01	0.00
Sc ₂ O ₃	0.00	0.22	0.00	0.11	0.27	0.02	0.02
Y ₂ O ₃	0.08	0.36	0.07	0.44	0.32	0.03	0.20
La ₂ O ₃	0.05	0.00	0.00	0.00	0.05	0.02	0.08
Ce ₂ O ₃	0.00	0.03	0.00	0.00	0.00	0.00	0.00
Pr ₂ O ₃	0.04	0.04	0.00	0.00	0.00	0.00	0.00
Nd ₂ O ₃	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SmO	0.09	0.00	0.18	0.01	0.00	0.07	0.07
EuO	0.05	0.02	0.02	0.01	0.00	0.02	0.05
Gd ₂ O ₃	0.08	0.04	0.00	0.23	0.00	0.00	0.00
Tb ₂ O ₃	0.00	0.00	0.04	0.00	0.00	0.00	0.05
Dy ₂ O ₃	0.07	0.00	0.00	0.00	0.16	0.13	0.00
Ho ₂ O ₃	0.00	0.09	0.00	0.00	0.00	0.09	0.04
Er ₂ O ₃	0.09	0.04	0.05	0.23	0.16	0.10	0.07
Tm ₂ O ₃	0.02	0.02	0.01	0.08	0.04	0.00	0.00
Yb ₂ O ₃	0.09	0.28	0.08	0.20	0.24	0.00	0.00
Bi ₂ O ₃	0.00	0.01	0.00	0.04	0.03	0.00	0.00
MnO	0.00	0.00	0.00	0.02	0.00	0.00	1.81
FeO	0.01	0.64	0.02	0.02	0.02	0.08	0.53
PbO	0.01	0.03	0.11	0.01	0.01	0.00	0.00
Total	100.27	101.53	101.39	101.90	99.73	101.06	99.64
Si ⁴⁺ (apfu)	0.969	0.974	0.998	0.985	0.989	0.996	0.977
Ti ⁴⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Zr ⁴⁺	1.010	0.969	0.981	0.975	0.966	0.981	0.922
Hf ⁴⁺	0.013	0.016	0.015	0.019	0.020	0.015	0.024
Th ⁴⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000
U ⁴⁺	0.000	0.004	0.000	0.002	0.005	0.000	0.008
Al ³⁺	0.000	0.002	0.000	0.000	0.000	0.000	0.000
Sc ³⁺	0.000	0.006	0.000	0.003	0.007	0.001	0.001
Y ³⁺	0.001	0.006	0.001	0.007	0.005	0.000	0.003
La ³⁺	0.001	0.000	0.000	0.000	0.001	0.000	0.001
Ce ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Pr ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Nd ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sm ²⁺	0.001	0.000	0.002	0.000	0.000	0.001	0.001
Eu ²⁺	0.001	0.000	0.000	0.000	0.000	0.000	0.001
Gd ³⁺	0.001	0.000	0.000	0.002	0.000	0.000	0.000
Tb ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.001
Dy ³⁺	0.001	0.000	0.000	0.000	0.002	0.001	0.000
Ho ³⁺	0.000	0.001	0.000	0.000	0.000	0.001	0.000
Er ³⁺	0.001	0.000	0.000	0.002	0.002	0.001	0.001
Tm ³⁺	0.000	0.000	0.000	0.001	0.000	0.000	0.000
Yb ³⁺	0.001	0.003	0.001	0.002	0.002	0.000	0.000
Bi ³⁺	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mn ²⁺	0.000	0.000	0.000	0.001	0.000	0.000	0.047
Fe ²⁺	0.000	0.016	0.001	0.001	0.001	0.002	0.014
Pb ²⁺	0.000	0.000	0.001	0.000	0.000	0.000	0.000
Zr/Hf	75.1	59.6	66.9	50.3	47.5	67.6	38.3

Appendix D.11: Electron microprobe analyses of sekaninaite.

Position within sekan. crystal	top rim	top rim	top rim	middle	middle	closer to the core	closer to the core	core
Sample	GAR1c-1	GAR1c-2	GAR1c-3	GAR1c-4	GAR1c-5	GAR1c-6	GAR1c-7	GAR2c-1
SiO ₂	46.18	46.25	45.25	46.24	45.03	45.63	45.78	45.20
Al ₂ O ₃	29.23	29.48	29.22	29.67	29.41	29.65	29.53	29.46
BeO*	1.06	0.74	0.37	0.72	0.00	0.09	0.31	0.00
MgO	3.92	3.94	3.86	3.98	3.97	3.95	3.96	3.87
MnO	2.79	2.79	2.66	3.81	2.74	2.88	2.78	2.73
FeO	10.54	10.55	10.53	9.43	10.44	10.86	10.71	10.78
CaO	0.06	0.03	0.04	0.05	0.03	0.05	0.03	0.07
Li ₂ O*	0.35	0.48	0.54	0.43	0.68	0.54	0.54	0.63
Na ₂ O	1.99	2.15	2.02	1.92	2.09	1.92	2.05	2.03
Total	96.12	96.40	94.48	96.25	94.39	95.58	95.69	94.77
Si	5	5	5	5	5	5	5	5
Al	3.730	3.757	3.804	3.781	3.850	3.829	3.801	3.841
Be	0.276	0.191	0.099	0.188	0.000	0.024	0.082	0.000
Mg	0.632	0.636	0.636	0.642	0.656	0.644	0.644	0.637
Mn	0.256	0.255	0.249	0.349	0.258	0.267	0.257	0.256
Fe ²⁺	0.955	0.953	0.973	0.853	0.970	0.996	0.978	0.997
Ca	0.006	0.003	0.004	0.005	0.004	0.005	0.003	0.008
Li	0.151	0.209	0.239	0.187	0.302	0.240	0.237	0.282
Na	0.419	0.451	0.433	0.403	0.450	0.407	0.434	0.436
O	18.005	18.002	18.003	18.004	18.038	18.004	18.002	18.020

*Note : formula calculated on the basis of Si=5. Li and Be contents were calculated using formula of Bertoldi et al. (2004).

Appendix D.11 (contd.): Electron microprobe analyses of sekaninaite.

Position within sekan. crystal	core	core	middle	middle	middle	middle	middle	middle
Sample	GAR2c-2	GAR2c-3	GAR2c-4	GAR2c-5	GAR2c-6	GAR2c-7	GAR2c-8	GAR2c-9
SiO ₂	45.54	46.18	44.68	45.80	45.29	45.60	45.36	45.63
Al ₂ O ₃	29.67	29.56	29.62	29.72	29.34	29.40	29.48	29.38
BeO*	0.00	0.83	0.00	0.11	0.17	0.59	0.00	0.32
MgO	3.81	3.89	3.89	3.88	3.85	3.87	3.95	3.95
MnO	2.84	2.89	2.85	2.99	2.81	3.18	2.84	2.65
FeO	10.69	10.63	10.76	10.87	10.46	9.88	11.05	10.71
CaO	0.05	0.04	0.05	0.05	0.07	0.05	0.06	0.03
Li ₂ O*	0.67	0.36	0.71	0.56	0.62	0.48	0.60	0.57
Na ₂ O	2.14	1.82	1.89	1.98	2.11	1.92	2.02	2.14
Total	95.42	96.21	94.45	95.96	94.71	94.97	95.35	95.37
Si	5	5	5	5	5	5	5	5
Al	3.839	3.772	3.906	3.825	3.818	3.799	3.830	3.794
Be	0.000	0.216	0.000	0.028	0.046	0.156	0.000	0.083
Mg	0.624	0.627	0.649	0.632	0.634	0.633	0.649	0.645
Mn	0.264	0.265	0.270	0.277	0.263	0.295	0.265	0.246
Fe ²⁺	0.982	0.962	1.007	0.992	0.965	0.906	1.019	0.981
Ca	0.006	0.005	0.006	0.006	0.008	0.006	0.007	0.003
Li	0.298	0.157	0.319	0.247	0.275	0.211	0.265	0.251
Na	0.455	0.383	0.410	0.420	0.452	0.409	0.432	0.455
O	18.011	18.004	18.155	18.004	18.006	18.004	18.034	18.002

Appendix D.11 (contd.): Electron microprobe analyses of sekaninaite.

Position within sekan. crystal	middle	middle	rim	rim	rim
Sample	GAR2c-10	GAR2c-11	GAR2c-12	GAR2c-13	GAR2c-14
SiO ₂	45.52	45.79	45.12	45.70	45.52
Al ₂ O ₃	29.75	29.63	29.57	29.40	29.68
BeO*	0.00	0.25	0.00	0.70	0.13
MgO	3.94	3.89	3.89	3.97	4.33
MnO	2.74	2.76	3.04	2.97	3.73
FeO	10.83	10.66	9.87	9.84	8.67
CaO	0.05	0.06	0.05	0.05	0.05
Li ₂ O*	0.61	0.59	0.69	0.46	0.62
Na ₂ O	1.94	2.08	2.05	1.92	2.00
Total	95.38	95.71	94.28	95.01	94.73
Si	5	5	5	5	5
Al	3.851	3.814	3.862	3.791	3.843
Be	0.000	0.066	0.000	0.185	0.033
Mg	0.645	0.633	0.643	0.647	0.709
Mn	0.255	0.255	0.285	0.275	0.347
Fe ²⁺	0.995	0.974	0.915	0.901	0.796
Ca	0.006	0.006	0.005	0.005	0.006
Li	0.268	0.258	0.307	0.201	0.272
Na	0.414	0.440	0.441	0.407	0.426
O	18.019	18.005	18.016	18.004	18.004