Titaniq Thermobarometry of Fabric Development in the Strafford Dome, Vermont: Linking Microstructures to Orogenic Processes

Kyle T. Ashley

University of Vermont

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TITANIQ THERMOBAROMETRY OF FABRIC DEVELOPMENT IN THE STRAFFORD DOME, VERMONT: LINKING MICROSTRUCTURES TO OROGENIC PROCESSES

A Thesis Presented
by
Kyle Thomas Ashley
to
The Faculty of the Graduate College
of
The University of Vermont

In Partial Fulfillment of the Requirements for the Degree of Master of Science
Specializing in Geology

October, 2011
Accepted by the Faculty of the Graduate College, The University of Vermont, in partial fulfillment of the requirements for the degree of Master of Science, specializing in Geology.

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Date: October, 2011
Abstract

Geochemical, microstructural and petrological analyses were conducted on metapelites from the Strafford Dome, Vermont. Samples record metamorphic conditions from biotite to peak kyanite/staurolite grade and preserve microstructures related to two Acadian nappe emplacement events. The purpose of this study was to test the validity and application of the Ti-in-quartz ("TitaniQ") thermobarometer to constraining pressure-temperature-timing-deformation (P-T-t-D) paths in metamorphic tectonites. Due to the nearly ubiquitous presence of quartz in continental rocks, the ability to apply this method would have significant implications for improving our ability to resolve tectonic histories.

Cathodoluminescence (CL) imaging on quartz was conducted to qualitatively assess the distribution of Ti in a single grain and/or compare neighboring crystals. X-ray mapping of garnet porphyroblasts was conducted to estimate P-T conditions during garnet growth to provide a framework for included quartz grains. P-T-X contour diagrams (used in P-T calculations for garnet growth) were constructed from data obtained by X-ray fluorescence analysis on bulk-rock chemistries. Secondary ion mass spectrometry analysis was conducted to constrain Ti concentrations in quartz due to the low [Ti] present in the Strafford samples (<10 ppm).

Analysis of the samples revealed [Ti] in zoned quartz grains that can be grouped and associated with certain P-T-D conditions. A majority of quartz grains have dark cores in CL images with low [Ti] (~2.5–3.5 ppm) in both matrix quartz and inclusions. Quartz inclusions in garnets that grew syn-tectonically with D2 have bright rims ~5.5 ppm. Matrix quartz, on the other hand, has rims with much higher [Ti] (~7.5–9.5 ppm). Comparing these Ti concentrations to summary P-T paths from previous studies suggests: quartz inclusions have rims recrystallized during the end of D1 deformation, matrix grains have rims re-equilibrated at peak P-T conditions post-D2 deformation, and the dark cores observed in CL images must be from early prograde or relics of the protolith.

The evaluation of the TitaniQ thermobarometer’s application to constrain P-T-t-D histories has highlighted some potential problems and significant benefits. To use the thermobarometer, either T or P must be independently constrained, which is often difficult to do given the many microstructural contexts of quartz in a single sample. This study capitalized on the ability to determine the relative timing of quartz (re)crystallization relative to garnet growth. Using another trace element thermobarometer would be ideal (e.g. Zr-in-rutile) for greater precision, although the relevant accessory phases may not be present and constraining the timing of re-equilibration is challenging. The abundance of quartz in continental rocks and the various microstructural occurrences of quartz in a single metamorphic tectonite provides additional opportunities to constrain points on the P-T-D path than conventional thermobarometers. The TitaniQ thermobarometer has the potential to yield deeper insights into the tectonic history of crustal rocks than previously available. These findings further elucidate the potential of the method for use in studies of metamorphic tectonites, continental tectonics and rheology.
Graciously dedicated to my parents,

Wayne and Vickie Ashley
Acknowledgements

I extend my greatest appreciation and thanks to Laura Webb for providing me with this exceptional research opportunity and for being a motivating and engaged advisor and mentor through the graduate experience. In the words of Arthur D. Little, “research serves to make building stones out of stumbling blocks,” and the construction of this thesis would not have been made possible without the efforts of Laura. I am also indebted to Arne Bomblies, Keith Klepies, Frank Spear and Robert Badger for their advice and reviews as members of my thesis committee. Their efforts have greatly shaped this document into what it is today.

Analytical work conducted at RPI was made possible through the technical assistance of Frank Spear and Jay Thomas. Their time and effort greatly helped in the collection of data for this project. It was a learning experience that I have immensely benefitted from. Also, I would like to extend my appreciation to Thomas Menard and Frank Spear for providing samples from their personal collection from the Strafford Dome that were vital to the success of this project.

This project would not have been possible without the financial support from grants received through the Vermont Geological Society (VGS), National Science Foundation (NSF; awarded to Laura Webb), and Laura’s start-up funds.

I am thankful for the academic support and guidance given to me from colleagues, friends and mentors during my undergraduate and graduate vocations at the State University of
New York (SUNY) College at Potsdam and the University of Vermont (UVM), respectfully. Having a bountiful resource of such wonderful and helpful people made the process much easier. I would especially like to thank Robert Badger (SUNY Potsdam) for mentoring me and greatly preparing me for graduate school, and his extensive support and encouragement that motivated me to conduct graduate studies. I know I wouldn't be here without him. Thanks to my fellow graduate students (UVM) for their mutual support and friendship throughout the trials and tribulations of graduate school.

Finally, thank you to my family. You are my life support and made it so much easier of a process. To my father and mother, Wayne and Vickie Ashley, who have always, and continue to, push me to be the best I can. The love and support from these two people have made me into what I am today and encourage me to always strive to be my best. To my brother, Keith, now serving in the United States NAVY, and my sister, Chiara: thank you for your support during this entire vocation.

“If we knew what we were doing, it wouldn’t be research”

~ Albert Einstein (1879 – 1955) ~
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Chapter I

Introduction

Quartz is a nearly ubiquitous mineral found in the continental crust. As a result of its abundance, the mineral has been of significant importance for various studies, including: crystallization, deformation mechanisms, and trace-element/crystal-lattice interactions. One result of these studies is the development and refinement of the Ti-in-quartz (or “TitaniQ”) thermobarometer. Much like similar trace-element thermobarometers (e.g. Zr-in-rutile, Ti-in-zircon), TitaniQ results from the substitution of Ti for the major cation (Si) in the crystal lattice, with substitution controlled by pressure and temperature during (re)crystallization (Wark and Watson, 2006; Thomas et al., 2010). This study was conducted to analyze the validity and applicability of the TitaniQ thermobarometer in constructing pressure-temperature-time-deformation ($P$-$T$-$t$-$D$) histories in metapelitic rocks, through the analysis of quartz to refine $P$-$T$ conditions of deformation events recorded in microstructures examined within tectonites, as well as to identify a procedure for using the method efficiently and effectively. In addition, this project analyzed quartz inclusions in garnet porphyroblasts to compare relationships between garnet growth, deformation and quartz recrystallization. The focus of garnet-bearing samples provides a useful $P$-$T$ framework to evaluate the ability of quartz grains in different microstructural contexts to record parts of the $P$-$T$-$D$ path. The abundance and stability of
quartz under various metamorphic conditions makes this study practical. The findings of this project will be evaluated to determine the usefulness and applicability of TitaniQ in tectonic studies. Findings from this study will be submitted for peer-review publication.

Since the initial development of the TitaniQ thermobarometer, the method has been applied to various rocks and environments, with further studies conducted to refine the method. The method was originally classified as a thermometer (Wark and Watson, 2006), with pressure dependence revealed through additional experiments (Thomas et al., 2010). Studies on the diffusion of Ti in quartz (Cherniak et al., 2007; Cherniak, 2010) and the effects of Ti on cathodoluminescence (CL) imaging (Wark and Spear, 2005; Rusk et al., 2006, 2008; Spear and Wark, 2009) have provided improved methods for analyzing the equilibration of Ti-in-quartz as well as qualitatively analyzing the distribution of Ti in the phase. TitaniQ has been applied to various studies, including: estimating temperatures for ultrahigh-temperature quartz veins (with rutile needles present; Sato and Santosh, 2007), indexing Ge/Ti for low-temperature (500-650 °C)/low-pressure (<2 kbar) igneous fractionation studies of charnockitic rocks (Jacamont and Larsen, 2009), partial melting of metapelitic rocks in ultrahigh-pressure conditions (Lang and Gilotti, 2007), and calculating temperature estimates of deformation in mylonites (Kohn and Northrup, 2009; Grujic et al., 2009).

The Strafford Dome, in eastern Vermont, was selected for this project because the petrological and structural histories of the rocks have been well constrained (Menard, 1991; Menard and Spear, 1994), providing an exceptional context for the samples being analyzed. In addition, the metapelitic rocks of the Strafford Dome contain rocks of various metamorphic grades (from chlorite- to peak kyanite/staurolite-grade) with various deformation events
preserved. Fabrics preserved in the samples represent prograde, peak and retrograde metamorphism associated with the Acadian Orogeny (397–350 Ma; Spear and Harrison, 1989).

Quartz recrystallization in different microstructural settings, such as inclusion trails in porphyroblasts and pressure shadows, will be examined and will permit development of a qualitative $P$-$T$-$D$ framework. Temperature or pressure will be quantified through [Ti] measurements and available independent constraints for $P$ or $T$. The results are interpreted in the context of $P$-$T$ paths and regional tectonic evolution. Table 1-1 contains mineral abbreviations, units and symbols used throughout this thesis.
### Table 1-1 Mineral abbreviations, units and symbols

<table>
<thead>
<tr>
<th>Mineral Abbreviations†</th>
<th>Ab</th>
<th>Albite</th>
<th>Grs</th>
<th>Grossularite</th>
<th>Prp</th>
<th>Pyrope</th>
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<tr>
<td>Abm</td>
<td>Alm</td>
<td>Almandine</td>
<td>Hem</td>
<td>Hematite</td>
<td>Qtz</td>
<td>Quartz</td>
</tr>
<tr>
<td>Amp</td>
<td>Hbk</td>
<td>Hornblende</td>
<td>Hbl</td>
<td>Hornblende</td>
<td>Rt</td>
<td>Rutile</td>
</tr>
<tr>
<td>And</td>
<td>Ili</td>
<td>Illite</td>
<td>SIl</td>
<td>Sillimanite</td>
<td></td>
<td></td>
</tr>
<tr>
<td>An</td>
<td>Ilm</td>
<td>Ilmenite</td>
<td>Sps</td>
<td>Spessartine</td>
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<td></td>
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<tr>
<td>Ath</td>
<td>Kfs</td>
<td>Kfeldspar</td>
<td>Spn</td>
<td>Sphene</td>
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</tr>
<tr>
<td>Bt</td>
<td>Ky</td>
<td>Kyanite</td>
<td>Spl</td>
<td>Spinel</td>
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<tr>
<td>Cal</td>
<td>Mgs</td>
<td>Magnesite</td>
<td>St</td>
<td>Staurolite</td>
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<td></td>
</tr>
<tr>
<td>Chl</td>
<td>Ms</td>
<td>Muscovite</td>
<td>Ttn</td>
<td>Titanite</td>
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<tr>
<td>Ep</td>
<td>Or</td>
<td>Orthoclase</td>
<td>Usp</td>
<td>Ulvöspinel</td>
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<td>Grt</td>
<td>Pl</td>
<td>Plagioclase</td>
<td></td>
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**Length (l or h)**

| m          | = meters |
| dm         | = decimeters | = $10^2$ m |
| km         | = kilometers | = $10^3$ m |
| cm         | = centimeters | = $10^2$ m |
| mm         | = millimeters | = $10^3$ m |
| μm         | = micrometers | = $10^6$ m |
| nm         | = nanometers | = $10^9$ m |
| Å         | = Angstrom | = $10^{-9}$ m | = 10 nm |

**Volume (V)**

| L          | = liter | = $10^3$ cm$^3$ |
| cm$^3$     | = cubic centimeter |

**Mass**

| g          | = gram |
| kg         | = kilogram | = $10^3$ g |

**Density (ρ)**

| g cm$^{-3}$ | = gram per cubic centimeter |

†After Kretz (1973)
Table 1-1 (cont.) Mineral abbreviations, units and symbols

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<tr>
<th>Concentration</th>
<th>Definition</th>
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<td>Wt %</td>
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<tr>
<td>ppm</td>
<td>parts per million</td>
<td>$10^{-6}$ Wt % = $10^{-3}$ ppm</td>
</tr>
<tr>
<td>ppb</td>
<td>parts per billion</td>
<td>$10^{-9}$ Wt % = $10^{-6}$ ppm</td>
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<tr>
<td>X</td>
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</tr>
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<td>kilobar</td>
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</tr>
<tr>
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<td>entropy change</td>
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</tr>
<tr>
<td>ΔV</td>
<td>volumetric change</td>
<td></td>
</tr>
<tr>
<td>R</td>
<td>gas constant (8.3145 J K$^{-1}$ mol$^{-1}$)</td>
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</tr>
<tr>
<td>ΔG$_{rxn}$</td>
<td>Gibbs free energy of reaction</td>
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<th>Definition</th>
<th>Conversion</th>
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<tr>
<td>λ</td>
<td>wavelength</td>
<td></td>
</tr>
<tr>
<td>$a_x^y$</td>
<td>activity of component x in phase y</td>
<td></td>
</tr>
<tr>
<td>2σ</td>
<td>two standard deviation of a Gaussian distribution</td>
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References


Chapter II

Literature Review

1. TitaniQ Thermobarometry

1.1 Theory and Trace Element Incorporation into Quartz

Investigation of trace element budgets in quartz has resulted in the establishment and refinement of the Ti-in-quartz (“TitaniQ”) thermobarometer with precision of temperature estimates on the order of ± 5°C (2σ; if pressure is well constrained; Wark and Watson, 2006; Thomas et al., 2010). Because quartz is nearly ubiquitous in rocks of the continental crust and is stable under various metamorphic conditions, TitaniQ provides new opportunities for precise thermobarometry and constraining pressure-temperature-time-deformation (P-T-t-D) histories of tectonites.

Trace element uptake into the quartz lattice has been well established through previous studies (e.g. Weil, 1984, 1993; Götze et al., 2004). Quartz is regarded to only incorporate a relatively small number of additional elements into its lattice because of the small size and structure of the Si$^{4+}$ ion. Incorporation into the quartz lattice is achieved through substitution for Si predominantly by Al, Ti, and Ge and interstitial filling (Li, Na, K; Figure 2-1; Götze et al.,
2004; Berry et al., 2007). Charge compensation must be accomplished for cations with 3+ valances (e.g. Al, Ge, Ga), which is achieved by the alkali ions (typically Li⁺). Ti isomorphically and isoelectronically substitutes for Si in the quartz lattice due to the tetravalent nature of both Ti and Si cations; substitution can be achieved without charge balancing through coupled substitution of other elements (Götze et al., 2004; Wark and Watson, 2006; Ostapenko et al., 2007). This was determined through studies in Ti coordination with X-ray absorption near-edge structure (XANES; Farges et al., 1996a, 1996b; Farges, 1997; Farges et al., 1997; Berry et al., 2007; Thomas et al., 2010), bond length studies using X-ray absorption fine structures (XAFS; Farges et al., 1996a, 1996b), and lattice parameter X-ray diffraction (XRD) studies relative to temperatures for quartz with rutile-needle inclusions produced from the β- to α-quartz transition (Ostapenko et al., 1987; Ostapenko et al., 2007).

1.2 TiO₂ Activity and Diffusion in Quartz

Solubility is dependent on the activity of TiO₂ in quartz (a_TiO₂^{qtz}), which is typically fixed when quartz is recrystallized in the presence of TiO₂ systems (e.g. rutile a_TiO₂ = 1; titanite a_TiO₂ = 0.5; Wark and Watson, 2006). In systems where TiO₂ is not an essential stoichiometric component, TiO₂ activity may be calculated (a_TiO₂ is ~1 for metapelites and ≥0.8 for amphibolite-facies felsic gneisses; Ghent and Stout, 1984; Wark and Watson, 2006). It is important to constrain this activity, for errors may arise from using the incorrect TiO₂ activity value (Figure 2-2). For example, assuming a_TiO₂ = 0.8 when in actuality a_TiO₂ = 0.6 at 800°C (10 kbar) results in temperature calculations ~25°C too high.
In rutile absent samples, ilmenite may be the phase constraining $a_{\text{TiO}_2}$. The metapelitic samples from the Strafford Dome often contain ilmenite and magnetite as primary opaque phases. To calculate for the activity of TiO$_2$ for these samples, the Gibbs free energy of a reaction ($\Delta G_{\text{rxn}}$) must be calculated from the Gibbs free energy of formation ($\Delta G_{f_{\text{fmn}}}$) for the reaction (Wark et al., 2007):

$$2 \text{FeTiO}_3 = \text{TiO}_2 + \text{Fe}_2\text{TiO}_4$$

at standard temperature and pressure (STP), where FeTiO$_3$ is ilmenite (Ti endmember of solid solution with hematite), TiO$_2$ is rutile, and Fe$_2$TiO$_4$ is ulvöspinel (Ti endmember of solid solution with magnetite; Figure 2-3). Gibbs free energy describes the affinity of a reaction, where $\Delta G < 0$ favors the reaction (spontaneous), $\Delta G > 0$ disfavors the reaction (nonspontaneous), and $\Delta G = 0$ is a reaction at equilibrium. Carleton University’s Science Education Resource Center (SERC) website has provided Holland and Powell’s (1998) open database of $\Delta G_{f_{\text{fmn}}}$ for various phases at reference state. For the reaction above, these values are: rutile = -1,011,667 J/mol; ilmenite = -1,371,394 J/mol; ulvöspinel = -1,716,946 J/mol. Substituting these values for the reaction above results in $\Delta G_{f_{\text{fmn}}} = 14,176$ J/mol.

The Gibbs free energy thermodynamic equation can be used to quantify the activity of TiO$_2$ in the system. The equation that relates changes in Gibbs free energy to temperature, entropy ($S$) and enthalpy ($H$) is (Spear, 1993):

$$G = H - TS$$  \hspace{1cm} (2-1)
therefore

\[ \Delta G = \Delta H - T\Delta S - S\Delta T \]  \hspace{1cm} (2-2)

The isothermal conditions \( \Delta T = 0 \) results in:

\[ \Delta G = \Delta H - T\Delta S \]  \hspace{1cm} (2-3)

A Van’t Hoff (or Vukancic-Vukovic equation) chemical thermodynamic reaction isotherm can be used in conjunction with the equilibrium constant that relates \( \Delta G_{\text{rxn}} \) to the chemical equilibrium constant. The resultant equation becomes:

\[ \Delta G_{\text{rxn}} = -RT\ln(K) \]  \hspace{1cm} (2-4)

where \( K \) is the equilibrium constant for the reaction, or the product of activities of the reaction products divided by the product of the activities of the reactants (Holland and Powell, 1998; Wark et al., 2007). Using the Fe-Ti-oxide reaction above (assuming ideality, \( a=X \)), the equation becomes:

\[ \Delta G_{\text{rxn}} = -RT \ln \left( \frac{a_{\text{TiO}_2} \cdot a_{\text{Fe}_2\text{TiO}_4}}{(a_{\text{Fe}_3\text{TiO}_5})^2} \right) \]  \hspace{1cm} (2-5)

The activities for ilmenite and ulvöspinel can be quantified as the mole fractions of Ti endmembers from measured compositions of ilmenite and ulvöspinel; much like plagioclase content is denoted as the percent anorthite (or An-content). For example, if a sample has ilmenite at 80%, and ulvöspinel at 25%, the resulting activities would be \( a_{\text{Fe}_3\text{TiO}_5} = 0.80 \) and \( a_{\text{Fe}_2\text{TiO}_4} = 0.25 \). For simplicity, the activity of ulvöspinel and ilmenite will be termed “X” and “Y,” respectfully. Eq. 2-5 can be rearranged to solve for the activity of TiO\(_2\) for the system:
If the temperature (in Kelvin) is known (which may be calculated through the Fe-Ti geothermometer with ilmenite and magnetite), the calculated \( \Delta G_{\text{rxn}} \), \( X \) and \( Y \) can be used to constrain \( a_{TiO_2} \) for the system. Using the example above, assuming 800 °C, the resulting \( a_{TiO_2} \) will be 0.52. Because reference state \( \Delta G_{f}^{\circ} \) values are being used to calculate \( a_{TiO_2} \) with this method, it is important to use values associated with the elevated \( P \) and \( T \) conditions during the metamorphic rock’s equilibration. Care must be taken when using this method however, because ilmenite may form hematite lamellae and re-equilibrate (Harlov, 2000; McEnroe et al., 2002). In addition it is important to note that metamorphic magnetite rarely has much of an ulvöspinel component, which makes this method preferred for magmatic rocks (Spear, personal communications). Extensive re-equilibration could significantly impact geothermal and activity calculations. For metapelitic samples, constraining Ti activity is less crucial since this value is usually ~1 and is rarely below 0.9 (Ghent and Stout, 1984).

The diffusion of \( Al^{3+} \) (Pankrath and Florke, 1994) and \( Ga^{3+} \) (Mizutani et al., 1982) into quartz is faster than \( Ti^{4+} \) diffusion; the higher charge of the Ti ion most likely accounts for this lower diffusivity (Cherniak et al., 2007). Si self-diffusion is slower than Ti diffusion (Cherniak, 2003). Calculated characteristic transport distances in which Ti diffuses in quartz are 2 \( \mu m \) and 5 \( \mu m \) in 1.0 and 10 Ma, respectively, at 500°C (Cherniak et al., 2004, 2007; Cherniak, 2010). This implies that either high temperatures, small grain sizes or long times are required to have cores record peak \( P-T \) conditions for equilibration during prograde metamorphism (for quartz that is not deforming or the product of a reaction).
1.3 Cathodoluminescence Analysis

Previous studies on cathodoluminescence (CL) imaging of quartz have shown that CL intensity at 415 nm (blue) wavelength is proportional to Ti concentrations due to the element’s CL emission properties (Wark and Spear, 2005; Rusk et al., 2006, 2008; Spear and Wark, 2009), which is useful in distribution analysis of Ti in a single crystal (i.e. zoning) or comparing neighboring crystals. Internal zoning of quartz grains can be interpreted for context of P-T analysis. For example, a quartz grain under CL may display a bright core and a darker rim, which could be attributed to increased pressures (possibly caused by nappe emplacement) or decreased temperatures during re-equilibration. Inclusions in garnet may contain bright rims caused from the diffusion of Ti from garnet to quartz (Spear and Wark, 2009). CL imaging quartz with a red filter also proves useful because the red intensity signifies electron damage to the sample, such as that acquired through back-scattered electron (BSE) imaging and spot analyses (Figure 2-4).

1.4 P-T Calculations

Pressure and temperature conditions during (re)crystallization controls the solubility of Ti in quartz (Wark and Watson, 2006; Thomas et al., 2010). For P-T determination, an independent estimate of pressure or temperature is required, or both can be obtained through simultaneous use with another thermobarometer (e.g. Zr-in-rutile, Zr-in-sphene, and Ti-in-zircon; Figure 2-5; Hayden et al., 2006; Watson et al., 2006; Thomas et al., 2010). Appendix A discusses the TitaniQ calculations in detail (including propagation of error) and Program
**ThermobarQ**, a MATLAB script written to perform various calculations for P-T estimates (including script and user manual).

2. Tectonics and Metamorphism of the Strafford Dome, Vermont, USA

2.1 Regional Geology

The Strafford Dome (Figure 2-6) is principally composed of the phyllitic/schistose Silurian to Early Devonian Waits River and Gile Mountain Formations (ages determined by fossil and U-Pb dating; Hueber et al., 1990), which collectively make up the Connecticut Valley Trough. The older Waits River Formation, inferred by stratigraphic tops in graded beds, isotopic analysis and fossil evidence (Doll, 1944; Fisher and Karabinos, 1980), consists of micaceous limestone, pelitic schists and the Standing Pond amphibolites. This formation is a calcareous flysch deposit, with dm to 10 m scaled interleaving of pelitic and carbonate layers. The Standing Pond Amphibolite is a thin (10–100 m) unit of basic metavolcanic material (Evans et al., 2002). The Gile Mountain Formation has similar lithologies as the Waits River Fm, although it has a paucity of limestone and has a profusion of quartz-mica schists and amphibolites (Doll, 1944), with pelites and psamites being the main constituents. Hatch (1988) described detailed lithologies and stratigraphies of the Waits River and Gile Mountain Formations.

The Monroe Fault to the east and the Richardson Memorial Contact (RMC) to the west separate the generalized anticlinorium structure from New Hampshire and pre-Silurian rocks, respectively (Hatch, 1988; Menard and Spear, 1994; Spear et al., 2002). The RMC unconformity is coincident with a high angle Devonian fault (Westerman, 1987; Hatch, 1988; McMillan et al., 2002).
The Strafford Dome is the northern-most of a series of N-S trending domes in eastern Vermont (Doll et al., 1961; Menard and Spear, 1994; Figure 2-6). The Gile Mountain Formation preserves sedimentary bedding locally (Woodland, 1977; Fisher and Karabinos, 1980; Menard and Spear, 1994), with bedding parallel micaceous schistosity (S<sub>1</sub>) created by an early folding event, D<sub>1</sub>, producing rare F<sub>1</sub> folds (White and Jahns, 1950; Menard, 1991; Menard and Spear, 1994). D<sub>2</sub> deformation caused S<sub>2</sub> schistosity, resulting in crenulation cleavage and large scale recumbent folds, F<sub>2</sub>, of S<sub>0</sub> and S<sub>1</sub> across the dome (White and Jahns, 1950) and is attributed to the emplacement of a nappe (Woodland, 1977). Structural data from the core of the dome reveals the doming of S<sub>2</sub> (Doll, 1944; White and Eric, 1944; Woodland, 1977; Menard and Spear, 1994). Widely spaced or local kink banding (S<sub>3</sub>) deforms S<sub>2</sub> (Woodland, 1977; Fisher and Karabinos, 1980). The doming and local kink banding may be attributed to the Mesozoic extensional brittle faulting that may be locally associated with the Monroe Fault (Menard and Spear, 1994). The structural and metamorphic scheme defined by Menard and Spear (1994) is used as a framework for this study and is the basis for terminology used throughout this manuscript.

2.2 Metamorphism

Initial metamorphism occurred in response to the Middle Devonian Acadian Orogeny (397–350 Ma; Spear and Harrison, 1989; Menard and Spear, 1994). Four distinct stages of metamorphism (Table 2-1) have been determined by Menard and Spear (1994). M<sub>1</sub> was produced by D<sub>1</sub> and consists of muscovite + biotite ± ilmenite, forming the S<sub>1</sub> schistosity. This constitutes the majority of the biotite grade metamorphic zone (Figure 2-6); the extent and
homogeneity of this zone suggests $P$-$T$ conditions remained constant for an extended period of
time. Biotite + muscovite ± plagioclase ± tourmaline ($M_2$; garnet grade metamorphism) form the
$S_2$ schistosity. In thin section, garnets contain straight ($S_1$) inclusion trails with pressure shadows
of quartz and mica in the $S_2$ foliation (Menard and Spear, 1994). Kyanite/staurolite grade (peak)
metamorphism near the Strafford Dome contains the paragenesis of kyanite + staurolite +
garnet + plagioclase + biotite ($M_3$) that overgrew $S_1$ and $S_2$ during the doming event.
Metamorphic grade decreases away from the center of the dome (Menard and Spear, 1994). A
retrograde metamorphic event post-dating $D_3$ (causing $M_4$) has a mineral assemblage that
partially replaces the previous metamorphic assemblages. Chlorite + K-feldspar ± biotite ±
calcite ± sericite is the paragenesis of this event.

Comprehensive $P$-$T$ conditions for the Strafford Dome have been previously compiled
(Figure 2-7). Temperatures of ~450°C and pressures of 6–8 kbar correspond with the end of $D_1$
(determined from Gibbs method modeling; Menard, 1991). Isobaric heating up to 480–540°C
followed increased pressures of 1–2 kbar and are attributed to $D_2$ and are associated with
progressive crenulation cleavage development. Temperatures of ~540 °C (at the flanks) and 600
°C (near the core of the dome) were reached during $M_3$ metamorphism.

2.3 Thermochronology

$^{40}$Ar/$^{39}$Ar dating of hornblende cooling (closure $T$, or $T_c$, of ~500°C) with grains in the $S_2$
orientation is 370±15 Ma (Spear and Harrison, 1989). Note that the $T_c$ for argon in hornblende is
an estimation, since $T_c$ is a function of cooling rate, diffusion radius (Harrison, 1981), and
composition (O’Nions et al., 1969). More recent studies by Laird et al. (1991) of similar amphiboles resulted in ages of 376±5 Ma. These data record regional cooling following maximum Acadian P-T conditions of 550-650°C at 8–11 kbar (Menard, 1991; Menard and Spear, 1994). Harrison et al. (1989) conducted 40Ar/39Ar analyses of muscovite, biotite and K-feldspar from central New Hampshire to eastern Vermont. Resulting closure ages for these minerals in eastern Vermont are: 345 Ma for muscovite (Tc = 375°C), 310 Ma for biotite (Tc = 325°C), 320-340 Ma for K-feldspar plateau (Tc = 250°C) and 170 Ma for K-feldspar intercept (Tc = 150°C). Factors, such as diffusivities, were accounted for in the closure temperature calculations in Harrison et al. (1989). Rapid unroofing caused rapid cooling to 250 °C by 310 Ma (Harrison et al., 1989; Menard and Spear, 1994).

3. Microstructures

3.1 Deformation Mechanisms of Quartz

Despite quartz being nearly ubiquitous in crustal rocks, more still must be known about the mineral’s behavior during deformation. The influence of water on quartz, for example, is quite evident and may greatly affect the strength of the crystal lattice (Paterson, 1986; Paterson, 1988; Luan and Paterson, 1992; Kronenberg, 1994; Gleason and Tullis, 1995; Kohlstedt et al., 1995; Post et al., 1996). Quartz behaves ductilely at relatively low temperatures compared with other mineral phases (e.g. feldspar). With varying deformation conditions, different mechanisms will operate and different slip systems will become active, as a function of
homologous temperatures, differential stress, strain rate ($\dot{\varepsilon}$), water fugacity ($f_{H_2O}$), and other factors (Stipp et al., 2002, and references therein).

To effectively analyze the usage of the TitaniQ thermobarometer in establishing $P$-$T$-$t$-$D$ histories, the drivers and processes of quartz recrystallization and deformation must be understood. The subsequent sections are focused on outlining mechanisms of dynamic recrystallization of quartz (Figure 2-8). Temperature regimes are presented as constraints for the mechanisms introduced, however it is important to note that varying conditions, such as those listed above, may change the temperatures at which the mechanisms become active. For example, sufficient water present during deformation may allow grain boundary migration recrystallization to become active at 450°C, rather than the stated 500°C (Luan and Paterson, 1992; Post et al., 1996). Also, there is typically an overlap between different deformation mechanisms; recrystallization mechanisms such as subgrain rotation recrystallization and grain boundary migration recrystallization may be active contemporaneously within a single sample (Stipp et al., 2002).

3.1.1 Very low-grade (<300°C)

Brittle fracturing (or cataclastic flow) is common in quartz at very low-grade conditions. It is common for fluid and solid inclusion trails to align with healed fractures (Dale, 1923; Spry, 1969; Richter and Simmons, 1977; Sprunt, 1979) with other dominant deformation mechanisms such as solution transfer of material and pressure solution present (Dunlap et al., 1997; van Daalen et al., 1999; Stipp et al., 2002). Pressure solution involves high differential stress-
induced dissolution, where solution transfer removes material via grain boundaries. Localities where crystal lattices are under high differential stress, selective pressure solution becomes more pronounced (Robin, 1978; Wheeler, 1987a, 1992; Knipe, 1989). Seams of insoluble material (or salvage) and strain-free pressure shadow crystals are examples of key identifiers for pressure solution. Patchy or sweeping undulose extinction and kink banding may also be present (Nishikawa and Takeshita, 1999).

3.1.2 Low-grade (~300 – 400°C)

Basal glide planes in the <a> direction accommodates dislocation glide and creep (Kruhl, 1996, and references therein), with sweeping/patchy undulose extinction and deformation lamellae occurring. At low temperatures bulging recrystallization (BLG), or localized grain boundary migration recrystallization, is dominant (Figure 2-8a; Stipp et al., 2002). With low-grade conditions, it is possible to have Dauphiné deformation twins (a penetrative twin with a {0 0 0 1} twinning axis formed as a result of transformation; Tullis, 1970; Barber and Wenk, 1991; Lloyd et al., 1992; Heidelbach et al., 2000; Lloyd, 2000).

3.1.3 Medium-grade (~400 – 500°C)

Prism slip in the <a> direction becomes active with dislocation creep dominating (Kruhl, 1996, and references therein) and pressure solution still occurring (den Brok, 1992). The subgrain rotation (SGR) recrystallization regime becomes dominant (Figure 2-8b; Lloyd and Freeman, 1994; Stipp et al., 2002). Ribbon grains are abundant and may be consumed by
subgrains (Hirth and Tullis, 1992; Stipp et al., 2002); the subgrains develop oblique foliations relative to the original ribbon grain. Recovery becomes abundant and important at higher temperatures (Passchier and Trouw, 2005).

3.1.4 High-grade (>500°C)

Grain boundary migration (GBM) is the dominant recrystallization mechanism, creating irregular lobate/amoeboid grain boundaries (Stipp et al., 2002; Figure 2-8c). Pinning microstructures are common due to the migration of grain boundaries (Jessel, 1987). At higher temperatures, rapid recovery and recrystallization removes dislocations, causing strain-free grains (White, 1977) and prism-slip \{m\}<c> becomes significant (Blumenfeld et al., 1986; Mainprice et al., 1986). Chessboard extinction in quartz may occur as a result of combined basal <a> and prism <c> slip (Blumenfeld et al., 1986; Mainprice et al., 1986; Stipp et al., 2002). Kruhl (1996) attributes this microstructure to the α-β quartz transition.

3.1.5 Static recrystallization

After deformation ceases, grains still contain dislocations and are not at a state of minimal free energy. Recovery, recrystallization and grain boundary area reduction (GBAR) may continue if temperatures (or water) remained high post-deformation. The passive heating or slow cooling of the rocks may be associated with static recrystallization and can result in a foam texture (120° triple junctions). Once dislocations are removed due to GBAR, grain boundaries become straight and grains tend to grow in size (Vernon, 1976; Poirier, 1985; Humphreys and
Hatherley, 1995; Humphreys, 1997; Kruhl, 2001; Evans et al., 2001). Cores may be retained and not swept by grain boundaries (Jessell et al., 2003). These cores can retain the chemical composition of the original grain, which proves useful in TitaniQ studies.

3.2 Crenulation Cleavage Development

Secondary foliations can exist as numerous morphological features. Crenulation cleavage is dominant in many of the samples from the Strafford Dome. Spaced foliations in rocks consist of cleavage domains and microlithons. Shelley (1993) classified M, P and Q domains for mica-, phyllosilicate- and quartz-rich domains, respectfully, in mica schists for simplicity purposes. Micas and accessory phases (e.g. ilmenite, rutile, zircon, etc.) are typical constituents of the cleavage domains (Gray, 1977). Cleavage domains can be described in a number of ways, including (but not limited to): spacing of the domains, shape of the domains and percent cleavage domains. Crenulation cleavage describes the presence of microfolds of an earlier foliation as microstructures in the microlithons (Rickard, 1961). Disjunctive cleavage is present when microfolds are absent.

Passchier and Trouw (2005) classify the main controls of secondary foliation development as being: rock composition, stress orientation and magnitude, metamorphic conditions, lithostatic pressure and fluid pressure/composition. Although many mechanisms (e.g. solution transfer, crystalplastic deformation, etc.) are important mechanisms in explaining the microstructures we see in thin section, the emphasis for this section will be on the process of microfolding and the development of spaced cleavage. The presence of older planar fabric in
conjunction with mechanical anisotropy may give way to crenulation cleavage (Passchier and Trouw, 2005). Solution transfer or recrystallization of grains will result in the development of spaced cleavage along the limbs of the microfolds if a certain amplitude is reached (Gray and Durney, 1979a, 1979b; Passchier and Trouw, 2005). In absence of folding of previous foliations, kinking (or disharmonic microfolding) of individual micas may result in preferred orientations through rotation away from shortening direction (Engelder and Marshak, 1985).

The development of spaced foliations has been postulated to involve the following mechanisms (see Passchier and Trouw, 2005, for a summary). Commonly, a form of the transportation of material through dissolution precipitation is required in conjunction with mechanical interaction. The presence of soluble minerals and a fluid phase is important in the development of spaced foliations. The sequence of mineral solubility (in decreasing mobility) is: calcite > quartz > feldspar > chlorite > biotite > muscovite > opaques (Gray and Durney, 1979a).

As a result, quartz, calcite, feldspar and chlorite tend to concentrate in the fold hinges, whereas micas and opaque phases are limited to the limbs (Passchier and Trouw, 2005). The efficiency of quartz mobility may result in a complete overgrowth of previous fabrics without crenulation development in psammites.

3.3 Porphyroblast Nucleation, Growth and Inclusion Trails

Porphyroblasts can be important in microstructural analysis for the ability to interpret the timing of metamorphism relative to deformation. Porphyroblast characteristics, such as the size and number of porphyroblasts, and the ability of the porphyroblasts' inclusion trails to
mimic the structure of the rock at the time of their growth, provides valuable information for inferring the tectonic history of the rock and the microstructural context of quartz within a given sample. With the presence of inclusion trails, growth can be correlated to specific deformation events. Care must be taken with porphyroblast analysis to ensure erroneous interpretations of internal foliations ($S_i$) patterns are not being made in cases where garnet porphyroblasts amalgamate (Passchier and Trouw, 2005, and references therein). The following is a short overview on porphyroblasts, although the reader is encouraged to read relevant sections from Passchier and Trouw (2005) for a more complete understanding of porphyroblast growth and inclusion trails.

3.3.1 Garnet nucleation and growth

The concentration and size of garnet porphyroblasts is dependent upon the growth rate and the number of nuclei present (Passchier and Trouw, 2005). The stability of small grains may become compromised due to the high surface free energies relative to larger grains (Poirier, 1985). Numerous suitable sites favorable for porphyroblast growth (stable nuclei) will result in numerous small grains (Figure 2-9a); if few sites are present, fewer large porphyroblasts will grow (Figure 2-9b). Conservative estimates on the growth rates of porphyroblasts 2 mm in diameter in less than 0.1 to 1.0 Myr has been suggested (e.g. Cashman and Ferry, 1988; Christensen et al., 1989; Burton and O’Nions, 1991; Paterson and Tobisch, 1992; Barker, 1994; Williams, 1994). Solid state diffusion or diffusion from fluids along the porphyroblasts’ grain boundaries are the main controllers of growth.
3.3.2 Included foliations

Adjacent grains to the growing porphyroblasts are a source of material for porphyroblast growth. Elements required for growth must be transported and may be supplied from these adjacent grains. Minerals that do not (or only partially) participate in the reactions that cause for the growth of the porphyroblast will be removed by dissolution and diffusion (Passchier and Trouw, 2005). Because of the exorbitant ion diffusion rates in high-grade (amphibolites and above) metamorphic rocks (since these rates are controlled by temperature), complete removal of these adjacent grains may occur resulting in inclusion-free, gem quality porphyroblasts. In the case of lower-grade metamorphism, it is less common for the complete removal of non-participating minerals with inclusions of these minerals resulting in the porphyroblast (known as passive inclusions; Figure 2-10; Passchier and Trouw, 2005). Typical inclusion minerals in garnet include: quartz, opaque minerals, zircon, monazite, apatite, rutile, sphene and epidote-group minerals. Mica inclusions are rare since they contain essential elements that aid in the growth of the porphyroblast and are usually completely consumed during porphyroblast growth. The primary driver of this occurrence is due to the limited mobility of Al ions in low-grade metamorphic rocks relative to other cations (e.g. Si, Fe, Mg, K, Ca; Slack et al., 1993). This limited mobility causes Al-silicates (such as garnet) to grow at Al-rich sites (like mica) with difficulty replacing phases without Al-essential stoichiometric components and results in the passive inclusion of these phases (Passchier and Trouw, 2005). If the surrounding rock contains foliations or preferred mineral grain orientations, inclusion trails that partially record these fabrics may result.
Inclusion trails in porphyroblasts can provide insight into the deformational history of a rock. The inclusion patterns can be interpreted and integrated with structural observations to determine the relative timing of porphyroblast growth within the sample (Figure 2-10). Identifying garnets that grew at different times can possibly allow for the analysis of multiple generations of quartz. Passchier and Trouw (2005) have provided a modified set of terminology and mathematical symbols to describe the observed porphyroblast-matrix relations for determining relative timing (Table 2-2).

The occurrences of pre-tectonic porphyroblasts are uncommon (in regionally-metamorphosed areas) and rarely described (Zwart, 1962; Fleming and Offler, 1968; Vernon et al., 1993a,b). Randomly oriented inclusions and/or sector zoning (Rice and Mitchell, 1991) may be indicators of pre-tectonic growth, although care must be made when making this interpretation (Figure 2-11). Porphyroblast growth inter-tectonically is growth that happens between two deformation events. Growth over a fabric in absence of deformation occurs, with the inclusions unaffected by later deformation. Passchier and Trouw (2005) classify oblique-$S_i$ porphyroblasts as porphyroblasts with straight inclusion trails ($S_i$) that are oblique to the matrix foliation ($S_o$; Figure 2-12a).

Unlike inter-tectonic growth, syn-kinematic porphyroblast growth occurs during a single phase of deformation (Passchier and Trouw, 2005). Inclusion trails are typically curved, unlike the random or straight inclusion trails present in pre- and inter-tectonic porphyroblasts (Figure 2-11). The porphyroblast may include micro-folds (termed helicitic folds) and contain a sigmoidal, spiral geometry (Figure 2-12b). These porphyroblasts have been referred to as “rotated” or “snowball” porphyroblasts for their indications of relative rotation with respect to
the matrix foliation; although this is discouraged by Passchier and Trouw (2005) since determination of movement can be problematic (Ramsay, 1962; Bell, 1985; Johnson, 1993a, 1993b, 1999b).

Post-tectonic porphyroblast growth is more easily identifiable since inclusion trails are continuous with the matrix foliation and there is no deflection of $S_o$, strain shadows, or other evidence of deformation present with respect to porphyroblast growth (Passchier and Trouw, 2005; Figure 2-11; Figure 2-12c).
Figure 2-1. Generalized structure of an impurity cluster in quartz (view is down the c-axis). Note how cations with a 3+ valance (e.g. Al<sup>3+</sup>) require coupled substitution with 1+ valance cations in interstitial fillings (e.g. Li<sup>+</sup> and K<sup>+</sup>), whereas Ti isoelectronically substitutes for Si. From Müller <i>et al.</i> (2003).

Figure 2-2. (a) Linear regression curves of varying TiO<sub>2</sub> activity values (calibrated at 10 kbar), where \( a_{TiO_2} = 1 \) in presence of rutile and \( a_{TiO_2} = 0.5 \) in presence of titanite. (b) Possible error curves in miscalculated TiO<sub>2</sub> activities for rutile-absent systems. Thick curves represent maximum temperature errors that may occur by mistakenly assuming rutile was present during quartz recrystallization. From Wark and Watson (2006).
Figure 2-3. Ti-Fe$^{2+}$-Fe$^{3+}$ ternary diagram illustrating the ilmenite-hematite and ulvöspinel-magnetite solid solutions. The mole fractions of the Ti endmembers are used in calculating activity in rutile-absent rocks.

Figure 2-4. CL imaging at ~600 λ (red) is useful for detecting electron damage to the sample surface. Imaged here is the result of BSE imaging, rastered over an area (dashed outline), and spot analysis (arrow). Damage is contained to the sample surface, and may be removed if damage is extensive and disrupts CL analysis.
Figure 2-5. TitaniQ thermobarometer for rutile- and titanite-present systems. An accurate pressure constraint will allow for temperature calculation, and vice-versa. Use of another thermobarometer (e.g. Zr-in-rutile) in conjunction can be used in absence of well constrained P-T conditions (see intersecting isopleths above). Modified from Thomas et al. (2010). Zr isopleths for rutile and titanite from Tomkins et al. (2007) and Hayden et al. (2007), respectively.
Figure 2-6. (a) Generalized geologic map of south-eastern Vermont, after Doll et al. (1961). SD – Strafford Dome; PD – Pomfret Dome; CD – Chester Dome; AD – Athens Dome. Inset map shows location of geologic map, with bands depicting major tectonic belts (modified from Spear et al., 2002): blue band – Eastern Vermont belt; orange band – Merimack belt. Dark rectangle is area shown by the geologic map. Modified from Menard and Spear (1994). (b) Metamorphic isograd for same study area shown in (a). P.S. – Plutonic Series. Polymetamorphic areas (denoted by diagonal lines) represent rocks that were previously (Precambrian) metamorphosed to sillimanite zone or higher, but were later (Paleozoic) subjected to lower grade metamorphism. Grades of these rocks are indicated by the color beneath the diagonal lines. Inset illustrates P-T paths for the Eastern Vermont tectonic belt (occurring at high pressures, clockwise path) and the Merrimack tectonic belt (occurring at low pressures and high temperatures, counter-clockwise path). Inset P-T figure from Spear et al. (2002). Numbered points are sample locations, with accompanying sample information in Table 4-1.
Figure 2-7. Summary $P$-$T$ paths for select rocks from the Strafford Dome (Menard, 1991; Spear and Menard, 1994; Spear et al., 2002). Ti-in-quartz isopleths (after Thomas et al., 2010) and $\text{Al}_2\text{SiO}_5$ stability fields (after Holdaway, 1971) shown. Isopleths are calibrated to a fixed TiO$_2$ activity of 1 (rutile present).
Table 2-1. Deformation and Metamorphism of the Strafford Dome

<table>
<thead>
<tr>
<th>Deformation Event†</th>
<th>Structure</th>
<th>$S_x$</th>
<th>$M/M$ Stage</th>
<th>Minerals</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>$D_1$ Nappe emplacement</td>
<td>Rare $F_1$ folds; slaty cleavage (bedding parallel)</td>
<td>$S_1$</td>
<td>$M_1$</td>
<td>Muscovite + biotite ± ilmenite</td>
<td></td>
</tr>
<tr>
<td>$D_2$ Nappe emplacement</td>
<td>Crenulation and folding of $S_0$ and $S_1$; large recumbent folds; transposition of earlier fabric</td>
<td>$S_2$</td>
<td>$M_2$</td>
<td>Biotite + muscovite ± plagioclase ± tourmaline + garnet</td>
<td>$S_2$ overgrows $S_0$ and $S_1$ during doming.</td>
</tr>
<tr>
<td>$D_3$ Doming</td>
<td>Local kink banding or spaced cleavage</td>
<td>$S_3$</td>
<td>$M_3$</td>
<td>Kyanite + staurolite + garnet + plagioclase + biotite</td>
<td></td>
</tr>
<tr>
<td>Post-$D_3$ Exhumation / Unroofing</td>
<td></td>
<td>$S_4$</td>
<td>$M_4$</td>
<td>Chlorite + K-feldspar ± biotite ± calcite ± sericite</td>
<td>Retrograde metamorphism; replaces previous mineral assemblage</td>
</tr>
</tbody>
</table>

† Initial metamorphism occurred in response to the Middle Devonian Acadian Orogeny (Menard and Spear, 1994). Deformation, structures and metamorphic paragenesis are from studies by Doll (1944), White and Eric (1944), Woodland (1977), Fisher and Karabinos (1980), White and Jahns (1950), Menard (1991), Menard and Spear (1994).
Figure 2-8. Dynamic quartz recrystallization microstructures (from Stipp et al., 2002). (a) Bulging (BLG) recrystallization occurs at low temperatures and has characteristic subgrains that surround grain boundaries, and to a lesser extent, microfractures. (b) Subgrain rotation (SGR) recrystallization occurs at intermediate temperatures and typically displays ribbon grains of quartz. Ribbons can be completely consumed by extensive recrystallization. Subgrains form an oblique foliation to that of the host ribbon grain. (c) Grain boundary migration (GBM) recrystallization occurs at high temperatures and is distinguishable by its lobate and irregular grain boundaries and grain sizes. Interfingering sutures are common.
Figure 2-9. Number and distribution of nuclei in a rock influences the size and number of porphyroblasts that result. (a) Numerous nuclei will result in many smaller porphyroblasts with few inclusions. (b) Few nucleation sites will result in fewer porphyroblasts, but each may be large with many inclusions. From Passchier and Trouw (2005).
Figure 2-10. (a) Illustration depicting the inclusion of various metapelitic domains (I-V) within garnet porphyroblasts (post-deformation). I: micaceous; II: fine-grained quartz; III: mica and quartz; IV: course-grained quartz; V: mica and opaque minerals. Modified from Passchier and Trouw (2005). (b) Garnet porphyroblast from sample 10SD03D showing strong similarities to the illustration in (a).
Figure 2-11. Potential porphyroblast representations for various growth timings relative to matrix deformation. (a and b) Rare pre-tectonic porphyroblasts are distinguished by their randomly oriented inclusions and deflected $S_e$ around the rigid porphyroblast. (c and d) Inter-tectonic porphyroblasts grew between two deformation events in the absence of deformation. Inclusion trails are typically straight, but may be more complex if numerous deformation events are present (e.g. c3). Later deformation is not included in the porphyroblast and deflection of $S_e$ occurs around the rigid grain. (e and f) Porphyroblast growth occurring during deformation will result in syn-tectonic grains; typically with curved or sigmodal inclusion trails. Distinguishing inter-tectonic from syn-tectonic porphyroblasts may be difficult since some differences may be subtle (e.g. d compared to f3). (g and h) Post-tectonic porphyroblasts grow after deformation ceases. $S_i$ is continuous with $S_e$ and no deflection of the matrix occurs due to growth (like observed in pre-, inter- and syn-tectonic porphyroblasts). From Passchier and Trouw (2005).
<table>
<thead>
<tr>
<th>Pre-tectonic</th>
<th>Inter-tectonic</th>
<th>Syn-tectonic</th>
<th>Post-tectonic</th>
</tr>
</thead>
<tbody>
<tr>
<td>P&lt;D&lt;1</td>
<td>D_n&lt;P&lt;D_n+1</td>
<td>D_n≥P</td>
<td>D_n&lt;P</td>
</tr>
<tr>
<td>a</td>
<td>c</td>
<td>e</td>
<td>g</td>
</tr>
<tr>
<td>b</td>
<td>d</td>
<td>f</td>
<td>h</td>
</tr>
</tbody>
</table>

- Presence of strain shadows common
- Deflection of $S_n$ around porphyroblasts
- Distinction between pre-, inter- and syn-tectonic porphyroblasts is only possible if inclusions are present

- No strain shadows
- No deflection of $S_n$ around porphyroblasts

Deformation does not cause folding of matrix foliation.
Terminology of the relation between porphyroblast growth timing relative to fabric development. Symbols are from Passchier and Trouw (2005):

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$D_n &lt; P$</td>
<td>Growth of porphyroblast ($P$) post-tectonic relative to deformation event $n$ ($D_n$)</td>
</tr>
<tr>
<td>$P &lt; D_1$</td>
<td>Growth of porphyroblast ($P$) pre-tectonic relative to deformation ($D_1$)</td>
</tr>
<tr>
<td>$D_n \exists P$</td>
<td>Growth of porphyroblast ($P$) syntectonic relative to deformation event $n$ ($D_n$)</td>
</tr>
<tr>
<td>$D_n \leq P$</td>
<td>Growth of porphyroblast ($P$) syn- to post-tectonic relative to deformation event $n$ ($D_n$)</td>
</tr>
<tr>
<td>$D_n &lt; P &lt; D_{n+1}$</td>
<td>Growth of porphyroblast ($P$) intertectonic between deformation events $n$ and $n+1$ ($D_n$ and $D_{n+1}$)</td>
</tr>
</tbody>
</table>
Figure 2-12. Garnet porphyroblasts recording growth during different times relative to deformation. (a) Inter-tectonic garnet growth (sample 09SD08A). S$_2$ linear inclusion trail within the porphyroblast is at an oblique angle to the S$_2$ matrix foliation. (b) "Snowball" garnet with a sigmodial inclusion trail during syn-tectonic growth (sample 10SD03B2). (c) Post-tectonic garnet that grew after deformation has ceased (sample 10SD03D). S$_i$ is continuous with S$_e$ with no deflection of the matrix foliation around the garnet.
References


Johnson, S. E., 1993b. Testing models for the development of spiral-shaped inclusion trails in garnet pophyroblasts: To rotate or not to rotate, that is the question. *Journal of Metamorphic Geology*, 11, 635-659.


Chapter III

Analytical Methods

1. Field Methods

Initial samples were analyzed from Menard and Spear’s research collection to aid in targeting sample locations throughout the Strafford Dome. Efforts were focused on the collection of oriented samples along a traverse across the metamorphic isograds of the dome from garnet to staurolite/kyanite grade. The biotite zone was excluded due to decreased metamorphic conditions that would result in lower [Ti] measurements. Samples were oriented with respect to the dominant foliation and lineation, if present. Equal-area stereonets were produced from this structural data to better correlate meso- and microscopic structures to regional geology. A set of guidelines were used for sample selection purposes during this project, including: the presence of quartz, samples spread out across the dome, various metamorphic grades collected and various microstructures present.
2. Laboratory Methods

There were numerous analytical methods used during the duration of this project. Each is described here with a brief overview of the method, operating conditions during analysis (if applicable) and any special considerations associated with conducting the analyses. Methodology for this project also involves a strategy regarding the order in which analyses were conducted. For example, backscattered electron (BSE) imaging or X-ray mapping of the target area before CL analysis will result in anomalies appearing in the collected CL image (more detail will be discussed about this later). In this case, CL would be recommended for analysis first, followed by other electron microprobe analytical techniques.

2.1 Sample Preparation

Thin sections were prepared for all of the collected samples, including an additional eight non-oriented samples of the T. Menard thesis collection provided by Frank Spear at Rensselaer Polytechnic Institute (RPI) in Troy, New York. Billets were cut oriented normal to foliation and parallel to lineation, or parallel to the down-dip direction in the absence of lineation. A second billet was prepared normal to the foliation and orthogonal to the first billet. These were sent out to be made into microprobe quality polished thin sections. High-quality polished (<1 µm surface roughness) thin sections are required with electron microprobe analysis (EMPA) and secondary ion mass spectrometry (SIMS) analysis to provide a flat surface for quantitative analysis and to remove artifacts for imaging purposes (e.g. X-ray elemental mapping).
Electron microprobe analysis on non-conductive samples, such as a typical thin section, requires a carbon coating. This allows for the dissipation of electrical charge on the surface of the thin section. For SIMS analysis, a high purity gold film ~100 nm thick is applied to the clean sample surface to electrically conduct the sample.

Additional preparation after electron microprobe analysis is recommended prior to SIMS analysis. Sample navigation with the mass spectrometer is through reflected light microscopy. To increase the efficiency of navigation, small target areas (typically >1 mm in diameter) were microdrilled, or a thin section saw was used to remove larger portions of the section. The drilled targets are placed on a flat surface with double-sided sticky tape within a one inch Al round. A small gap around the internal circumference is allowed because this area cannot be analyzed with the SIMS. An epoxy solution is carefully poured over the samples, which are then briefly placed under a vacuum to evacuate any gas bubbles that may disrupt the conductivity of the samples (once coated) and are left to slowly cure overnight. Air bubbles may also be removed manually with a needle, “grabbing” the bubble and transporting it to the epoxy surface. Numerous targets from multiple thin sections can be combined into one round (Figure 3-1), or “puck,” greatly saving navigation and sample exchange time during analysis. If this route is taken however, it is strongly recommended to extensively photodocument the thin section before removing the targeted areas.

Separate sample preparation is required for major and minor trace element analysis using X-ray fluorescence (XRF). A representative rock sample must be crushed and powdered finer than 175 µm (sample should pass through an 80-mesh screen). The samples were shipped to the X-ray laboratory at Franklin and Marshall College for additional preparation and analysis.
Major element analysis requires 3.6 grams of Li$_2$B$_4$O$_7$ (a borate flux) to be combined with 0.4 grams of the rock powder. The sample is melted in a Pt crucible, and immediately quenched in a Pt casting dish, resulting in a glass dish required for XRF analysis. For trace element analysis, 7.0000 ± 0.0004 grams of the powder is combined with 1.4000 ± 0.0002 grams of high-purity Copolywax powder, which is then pressed into a briquette.

2.2 Microstructural Analysis

Extensive microstructural analysis of the collected samples is an important step in providing a framework for targeting sites for analysis, as well as for data interpretation (methods summarized in Chapter II, part 3). In some instances, inferences regarding P and T of deformation based on microstructures can be used to compare with [Ti] analyses and $P$-$T$ calculations (e.g. quartz recrystallization fabrics). Numerous generations of quartz (re)crystallization may be recognized with this analysis. Possible contexts may include, but are not limited to: subgrains, ribbon grains, garnet inclusions, pressure shadows, veins (various generations relative to deformation) and crenulated and slaty cleavage matrix material. Recognition of the $P$-$T$-$D$ context for all quartz grains analyzed as part of this study is an essential first step. Targets for further analyses are selected only after microstructural analyses are completed.
2.3 Cathodoluminescence (CL)

The utility of employing CL in mapping Ti distribution in quartz has been previously mentioned. Some elements (e.g. P, Ti or Zr) serve as CL “activators,” efficiently producing emissions even in trace quantities (Reed, 2005). “Quenching” may occur with the presence of certain elements, such as divalent Fe (like that present in almandine garnet), resulting in phases that appear dark or black under CL.

The process of CL analysis involves impinging an electron beam onto a mineral with activator elements, which in turn causes the excitement of an electron from the valence to the conduction band (Reed, 2005). An electron will recombine to the resultant hole, releasing energy (possibly as an emitted photon). The presence of lattice defects, mineral purity and other factors contribute to the energy (or color) of the released photon and the probability that a photon, not a phonon (a quasiparticle that represents the lattice vibrations in a solid), is emitted (Figure 3-2). A higher density of defects is the reason microfractures in quartz appear brighter in CL (Watt et al., 2000).

CL imaging was performed using the Cameca SX-100 electron microprobe setup equipped with a Gatan Mono-CL detector at RPI. An electron beam passes through a 1-mm hole in a parabolic mirror (results in increased sensitivity) attached to the end of a light finger. Raster imaging size was limited to several hundred microns due to limitations by the detector’s setup. Images are collected using a 10 nA beam current (Faraday cup measurement) and 15 kV accelerating potential. Beam rastering across an area collects visible light resulting from luminescent material. Dwell times of ~0.5—1.0 ms pixel\(^{-1}\) for all images were held constant without any pronounced streaking (see Spear and Wark, 2009, for details). Images were
collected in panchromatic, blue-, red- and green-filtered light; RBG images were created through the combination of the three wavelength-specific images (Figure 3-3).

Several complications may arise while conducting CL analysis that may hamper the usefulness and quality of the images collected. First, although phases like almandine garnet and other phases with ferrous Fe present should appear dark or black under CL, a coating of pump oil on the mirror resulting from extensive use may develop and cause false brightness in these phases (Figure 3-4a). This phenomena appears to reflect atomic mass (correlating to increasing Z-values) similar to that viewed in back-scattered electron (BSE) imaging. Removal of the oil corrects this problem and results in expected CL emissions. Another problem that may arise is the off-alignment of the mirror relative to the camera. An off-centered mirror appears to cause gradation in CL intensity across the image, with higher CL intensities near the center of the mirror, decreasing radially outward (Figure 3-4b). In addition, a smaller area is imaged to avoid the edge of the mirror (Figure 3-4c), which has its own set of complications. If the area analyzed is too small, the image may appear grainy and quality will diminish. Both of these problems should be simple corrections that can be made by the probe’s technician and will result in significantly improved image quality.

Besides the potential equipment complications that can hamper imaging quality, a few other tips should be mentioned to allow for the highest quality images possible during the analysis. First, it is observed that using a blue-filter requires higher voltage than imaging in panchromatic light. A safety feature set by the Gatan system prevents excessive voltage from being used, which typically is not a problem with proper adjustment of contrast and brightness, although it may result in grainier images. It is recommended to use lower voltages and to adjust
the images manually in imaging software (e.g. ImageJ). Another problem that may arise is the presence of phases that have significantly higher relative emissions than that resulting from the trace concentrations of Ti in quartz (e.g. zircon or monazite). The intensity of these phases will cause any zoning that may be observed in the quartz grains to be suppressed, and may result in streaking during rastering that will diminish the quality of the resulting image (due to auto-contrast). In most metapelitic samples, these phases are probably present and it is best to try and avoid these phases in the field of view during imaging to prevent this problem from occurring. Lastly, the CL camera does not have a scale associated with the field of view. It is recommended to take BSE images of the CL locations (after CL image is collected) to provide a reference scale for the images, to better distinguish the mineral phases present in the images and to make note of any cracks or fractures that may be present in the grains. If all of these factors are taken into account during analysis, the resulting images should be of the highest quality for Ti distribution analysis in quartz. False-coloring the resultant grayscale images in imaging editing software may prove useful to distinguish more subtle differences in [Ti].

2.4 Electron Microprobe Analysis (EMPA)

The electron microprobe is widely used in geology for analytical purposes (quantitative and qualitative). Various techniques used during analysis exploit the variety of ways the principle electron beam interacts with the sample surface. For example, BSE imaging utilizes the deflected electrons (more will be discussed with this method later), whereas CL imaging uses emitted photons from the electron transition between the conduction and valence bands after
excitement. These phenomena result in a machine that is highly versatile and can be applied to numerous projects, and may be integrated for more encompassing analyses.

EMPA analysis was conducted on the Cameca SX-100 electron microprobe at RPI. The microprobe is equipped with five wavelength dispersive spectrometers (WDS) and one energy dispersive spectrometer (EDS). The WDS contains oversized, high-sensitivity crystals that allow for precise trace elemental quantitative analysis with significantly increased count rates while maintaining peak-to-background ratios. Crystals used include PET, TAP and LiF; each of which produce optimum peak shapes for select elements (Figure 3-5) determined through Bragg’s law and their known 2d. Typical beam width for analysis is <1 µm, with beam rastering over an area for 2-D analysis. Thin sections must be prepared with a high microprobe-quality polish to allow for proper analysis and focusing.

2.4.1 Backscattered electron (BSE) imaging

When a sample is struck with a 15 kV, 20 nA incident electron beam, electrons may be deflected. The amount of electrons deflected is quantified as the backscattering coefficient ($\eta$), which is dependent on atomic number ($Z$) due to an increase in electron densities with higher $Z$ (Figure 3-6). This phenomena results in images where phases containing high $Z$ atoms appear brighter (e.g. garnet appears brighter than quartz; Figure 3-7).
2.4.2 X-ray elemental mapping

X-ray elemental mapping records X-ray photon counts for specific elements for an area of a sample. The WD spectrometer is used to count these photons for a fixed time for a given pixel, with the counts later converted to a grey-scale image depicting intensities. Absolute intensities (or concentrations) are lost during this process and each map must be chemically calibrated for further analysis (Reed, 2005). Because the lower yield of X-rays relative to backscattered electrons, for example, much longer dwell times to achieve acceptable image qualities are required. The end result is a 2-D map of the sample area that qualitatively shows the distributions of various elements (which becomes very useful in Al-silicate analysis, as will be discussed later).

X-ray maps are collected at 20 kV accelerating potential and 200 nA beam current. The high current in conjunction with WDS mapping allows for smaller dead times which result in less noise in images due to higher count rates (Reed, 2005). Elements mapped for this project include Al, Ca, Fe, Mg, Mn and Ti (Figure 3-8). A typical scan for a porphyroblast several mm in diameter takes between four and six hours. Large porphyroblasts require numerous tiles to be mapped, which are later combined after the scan. The grey-scale maps are false-colored in ImageJ for increased contrast in elemental distributions. Further analysis (profiling) of these images can be achieved, and will be discussed in detail later.

In addition to mapping garnet porphyroblasts, low-resolution thin section maps may be acquired for further analysis (Figure 3-9). Ti, Fe, Ca and Mg maps are collected for emphasis on Ti accessory phases (e.g. rutile, ilmenite, ulvöspinel, titanite, etc.) throughout the sample. This is important in identifying phases for constraining $a_{TiO_2}$ or for using another thermobarometer for
P or T constraints in conjunction with the TitaniQ thermobarometer. This method is useful because the map preserves pixel parameters and simply clicking on the image (with the proper mode selected for) will allow the sample to be centered on that pixel. This makes navigating the sample for these accessory phases quick, and EDS analysis can be done to confirm the phase present. The maps can also be used for petrological analysis. For example, Figure 3-9a (Ti map) shows significant ilmenite inclusions in the garnet porphyroblast, but very few in the matrix. A possible interpretation may be that post-garnet growth experienced an ilmenite-consuming reaction.

One complication that must be overcome when mapping larger areas is the defocusing that typically occurs around the image edges. Since the sample surface is rarely level, navigating any significant distance results in subtle changes in sample height (z) and, thus, the defocusing. This problem can be avoided by referencing each corner of the target map in acquisitions for x-, y- and z-parameters. When completed, the microprobe contours the z position over the area of the map which corrects for this problem.

Although X-ray mapping of a garnet might show, for example, concentric zoning from core to rim, electron backscattered diffraction (EBSD) is recommended to test whether this zoning is consistent with growth of a single porphyroblast. Studies have shown that amalgamation of garnets can occur and not show in elemental mapping (Whitney and Seaton, 2010). Whitney et al. (2008) reported nearly 30% of the garnets analyzed from the Barrovian-sequence rocks in southeast Vermont were actually polycrystalline in nature. Only when analyzing the structural orientation of these garnets through scanning EBSD did this amalgamation become evident. The presence of polycrystals with continuous (undisrupted),
concentric chemical zonation may suggest that post-growth modification occurred; possibly as diffusion zoning reflecting change in external conditions (Spear, 1993).

2.4.3 Quantitative spot analysis

Quantitative spot analysis was utilized with the EMPA for two purposes: to measure [Ti] for TitaniQ thermobarometry and to calibrate the X-ray elemental maps for quantitative distribution analysis. In both cases, quartz standardization condition of 20 nA is used to avoid pulse-height analyzer peak shifts (Thomas et al., 2010). Quantitative spot analyses were conducted using a 200 nA beam current and 15 kV acceleration potential. For [Ti] analysis, four spectrometers counted for Ti Kα X-rays with 400 second count times (~1,300 cps nA⁻¹). Typical detection limits of ~5.5 ppm (2σ) were obtained. The fifth spectrometer was used to measure Si Kβ X-rays to ensure analysis of a quartz phase (~18 cps nA⁻¹). Garnet analyses required use of all five spectrometers for elemental analysis, including: Si, Ti, Al, Cr, V, Mg, Ca, Mn, Zn and Fe. The standards used for probe calibration were (Table 3-1): pyrope (Kakanui, New Zealand) for Mg, Al and Si, Di₂Ti for Ca, rutile for Ti, chromite for Cr, V₂O₅ for V, tephroite for Mn, and fayalite for Fe. Standard calibration output results as measured elemental concentrations divided by the known standard concentrations. This should result in 1.00 for elements for which the standard was targeted. For improved conditions, any analysis measurement > ±0.01 from 1.00 was recalibrated. For garnet spot analysis, it is recommended to collect data for 5–7 spots and average the measurements to assure consistency. This should be repeated for elemental highs and lows corresponding to collected X-ray maps.
2.5 Secondary Ionization Mass Spectrometry (SIMS)

Due to the detection limits of the electron microprobe’s spot analysis for [Ti], SIMS was utilized for trace-element analysis. In this technique, the sample is bombarded by a primary beam of ions (O⁺ for cation analysis) generated via a duoplasmatron source (Figure 3-10) under ultra-high vacuum (< 1E-7 Pa), creating secondary ions in the process (Coath and Long, 1995, and references therein; Stern, 2009). Multiple generations of quasielastic collisions of target atoms, or a “collision cascade” (Sigmund, 1969), results in the sputtering of atoms from the surface of the sample (Figure 3-11). An upward of tens of secondary ions may be created during this process; frequently neutral atoms are sputtered and fall back down to the sample surface (Stern, 2009). Minimal heating/vaporization occurs relative to other trace elemental analytical methods (e.g. laser ablation), which results in less sample loss during analysis; although since the surface is bombarded and jostled during the process, a pit is created and analysis is collected in real-time relative to depth of analysis (Figure 3-12). Sputtered material is usually emitted from the top several atomic layers (<0.5 nm; Stern, 2009), whereas the ion beam penetrates significantly deeper (~10 nm). Structural damage to the crystal causes the sputtered surface to become an “amorphous selvedge” (Benninghoven et al., 1987).

The Cameca IMS 1280, equipped with a double-focusing high mass spectrometer and a large radius magnetic sector, at Woods Hole Oceanographic Institute (WHOI), MA, was selected for Ti spot analysis for this project. Detection limits using this technique are considerably smaller for the metapelitic samples being analyzed, with analytical standard deviations typically ~0.2–0.4 ppm. The incident ion beam had an impact energy of ~23 kV acceleration potential, with a current typically ~4.05 nA. A 240 second pre-sputter was used to remove a significant
portion of surface contamination, with 10 analytical cycles of 28 second dwell times used for data collection. Mass-peak calibrations were done for $^{30}\text{Si}$, $^{40}\text{Ca}$ and $^{48}\text{Ti}$ prior to each analysis, which attributed to an overall analysis time of 10–12 minutes for each spot location. Four standards of synthetic quartz with various known [Ti] were used and provided by the RPI group (see Appendix C for calibration results): Qtip7 (19.5 ppm), Qtip 14 (100 ppm), Qtip38 (380 ppm) and Qtip39 (813 ppm). Beam width varied slightly with focusing, which was factored into spot selection for analyses, and was typically 10–15 µm in diameter. A sputter halo is created during this process that appears much larger than the actual analyzed area (~20–30 µm).

In nature, both $^{48}\text{Ti}$ and $^{48}\text{Ca}$ occur in significant, measurable abundances. Because of the isobaric interference of $^{48}\text{Ca}$ on $^{48}\text{Ti}$, $^{40}\text{Ca}$ was measured in each analysis to correct for the contribution of $^{48}\text{Ca}$ at the mass 48 peak. For higher [Ti] (e.g. Ti > 5 ppm), this correction becomes less significant because the correction becomes minimal relative to concentrations and detection limits. Knowing the natural abundance of $^{48}\text{Ca}/^{40}\text{Ca}$ in nature (0.00186), we can calculate the corrected $^{48}\text{Ti}/^{30}\text{Si}$ for each analysis:

$$
\left( \frac{^{48}\text{Ti}}{^{30}\text{Si}} \right)_{\text{corr.}} = \left( \frac{^{48}\text{Ti}}{^{30}\text{Si}} \right)_{\text{meas.}} - \left( \frac{^{40}\text{Ca}}{^{30}\text{Si}} \right)_{\text{meas.}} \times \left( \frac{^{48}\text{Ca}}{^{40}\text{Ca}} \right)
$$  \hspace{1cm} (3-1)

The quantification of elements/isotopes is achieved through measuring the ratio of two secondary ion intensities (e.g. $^{48}\text{Ti}^{30}\text{Si}$; Stern, 2009). For Ti analysis, four standards of varying [Ti] (from 19.5 to 813 ppm) are measured, with a calibration plot created of known Ti (ppm) against measured $^{48}\text{Ti}/^{30}\text{Si}$ (counts; Figure 3-13). The equation of the best-fit line is used to calculate Ti concentrations in the analyzed samples.
Although the analytical standard deviations are significantly improved relative to the electron microprobe (±0.2 ppm relative to ±6 ppm, respectfully), there are several disadvantages when selecting SIMS analysis rather than EMPA. As mentioned earlier, there are difficulties in navigating the samples (which takes away from analytical time) and dwell times are significantly longer (~10 minutes for 10 cycles). Further, a larger beam size (~10–15 µm) places restrictions on spatial precision and what can be measured in the sample.

2.6 X-ray Fluorescence (XRF) Bulk-Rock Analysis

XRF analysis was conducted on various samples to acquire bulk-rock chemistries of various samples in the Strafford Dome that were selected for further analysis. The bulk-rock chemistries are required for the creation of P-T-X contour diagrams, which is utilized in the P-T analysis of garnet growth which establishes a reference framework for quartz inclusions in porphyroblasts. In addition, bulk-rock chemistries are used in the creation of pseudosections rather than petrogenetic grids to limit reactions that take place for the samples analyzed (more will be discussed later about this).

The physics behind XRF analysis is strikingly similar to that of previous methods mentioned, but rather than a principle electron beam (in the case of CL) being utilized, the X-ray portion of the electro-magnetic spectrum is targeted at the sample. The lower energies associated with CL analysis result in the excitation of the electrons from the valance- to the conduction band. High energy X-rays are capable of penetrating much deeper in the electron orbitals. Principle quantum numbers (n) associated with these orbitals result in characteristic X-
The distance between the conduction band and the orbital the electron returns to results in specific energy-levels, which are characterized as spectra for each element. For example, the energy difference of an electron transition from the M sub to the K sub-orbital (Kβ₁) is 24.938 keV for silver (Z=47; Figure 3-15). Quantitative analysis arises from the measured intensities of these X-ray spectra.

XRF analysis was conducted on four samples on a PANalytical X’pert Pro X-ray diffractometer equipped with a 4 kW Rh X-ray tube at Franklin and Marshall College, Lancaster, Pa. For light elements (Si through Na), the XRF operates at 32 kV and 125 mA. For elements with higher Z, the acceleration potential is increased and the current is decreased. A 60 kV voltage and 66 mA current is eventually reached for the remaining elements analyzed (e.g. Rb, Sr, Y, Zr, Nb, etc.). Major elements analyzed include (in oxide forms, as weight %): SiO₂, Al₂O₃, CaO, K₂O, P₂O₅, TiO₂, Fe₂O₃, MnO, Na₂O and MgO. The analysis measures total Fe as Fe₂O₃, although ferrous Fe can be determined through titration and loss on ignition of a sample aliquot at 950°C for one hour; this procedure is a modification of the Reichen and Fahey (1962) method. Geologic standards from Abbey (1983) and Govidaraju (1994) were used to calibrate the samples’ working curves. Trace elements analyzed during XRF analysis includes (in ppm): Rb, Sr, Y, Zr, V, Ni, Cr, Nb, Ga, Cu, Zn, Co, Ba, La, Ce, U, Th, Sc and Pb.
2.7 Pseudosections and Garnet Analysis: Gibbs Free Energy

2.7.1 Pseudosections

In metamorphic petrology, it is important to know the mineral assemblages in equilibrium during metamorphism. A pseudosection, a type of phase diagram that exemplifies the stability fields of various mineral assemblages in equilibrium for a particular bulk-rock composition, is used to model the reactions that take place in $P-T$ space (Figure 3-16). They are similar to petrogenetic grids (or $P-T$ grids), with the difference that $P-T$ grids show all possible reactions for a particular system (e.g. KFMASH) – even those that might not occur for the bulk-rock composition being analyzed. The reason this might be of importance is because when constructing $P-T$ paths for the sample, the user can gain insight into the assemblage sequence and the reactions that take place during pro- and retrograde metamorphism. Spear (1993) provides $P-T$ grids for various systems and “typical” rock types and is recommended reading for further information.

Published pseudosections for similar pelitic rocks were used to define metamorphic paragenesis and reactions that occurred (e.g. Spear, 1993; White et al., 2000; Tinkham et al., 2001). The bulk-rock chemistries are required to construct these plots. In addition, all of the phases wished to be considered are required prior to making the plot (although not all phases should be included, since this would result in exhaustively long calculation times). Calculations are completed using simple matrix inversion for linear equations (Gibbs’ method) of differential thermodynamics. This is beneficial since $\Delta H_{\text{reaction}}$ is not needed for every reaction (Spear, 1993).
2.7.2 Creating garnet profiles

Garnet profiles that display the chemical mole fraction (X) of garnet compositional components (e.g. almandine, pyrope, etc.) is an important analytical technique that graphically displays the zonation in garnet, and can be directly used in P-T calculations of garnet growth if integrated with P-T-X contour plots. There are two groups of garnet endmember species: the pyralspite group, where Al is in the Y-site of the generalized formula for garnet, and the urgrandite group, where Ca is in the X-site (as shown below):

$$X_3Y_2(SiO_4)_3$$

<table>
<thead>
<tr>
<th>Pyralspite group (Al in Y site)</th>
<th>Ugrandite group (Ca in X site)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Almandine†</td>
<td>Andradite Ca$_3$Fe$_2$(SiO$_4$)$_3$</td>
</tr>
<tr>
<td>Pyrope†</td>
<td>Grossular† Ca$_3$Al$_2$(SiO$_4$)$_3$</td>
</tr>
<tr>
<td>Spessartine†</td>
<td>Grossular† Ca$_3$Al$_2$(SiO$_4$)$_3$</td>
</tr>
<tr>
<td></td>
<td>Uvarovite Ca$_3$Cr$_2$(SiO$_4$)$_3$</td>
</tr>
</tbody>
</table>

†Al-silicate garnet varieties used in P-T-X calculations for the Strafford Dome.

Because the garnets present in the Strafford Dome are Al-silicates, we analyze for only four garnet species: almandine, pyrope, spessartine and grossular. Several common varieties of garnet representing cation endmembers have been recognized. These endmembers are useful when describing the mole fraction of a variety of garnet to the composition of the garnet being analyzed.

Two items are required prior to creating a chemical profile: a qualitative X-ray elemental map and spot analyses (for map calibration and mole fraction calculations). Electron microprobe analysis should yield the major cations in weight percent (wt %), in oxide form.
Weight oxides can be calculated with known elemental atomic masses and oxide formulas (Table 3-2). Mole fraction of a garnet species can be calculated for using the relationship:

\[ X_A^{grt} = \frac{\text{moles of component } A}{\sum \text{moles of mixture}} \]  

(3-2)

Almandine, for example, would be:

\[ X_{Alm}^{grt} = \frac{Fe \text{ (mol)}}{Fe + Mg + Ca + Mn + Zn + Cr + V \text{ (mol)}} \]  

(3-3)

A similar formula may be used for the other three components, with simply substituting the solute with the appropriate cation. To calculate moles of each cation in the garnet, a few intermediate steps must be taken first. The formula needs to be normalized with respect to the oxides and the generalized garnet formula (assuming 24 oxygen atoms). This equation is:

\[ O_{norm.} = \frac{\sum_{i=SiO_2}^n \left( \frac{\text{wt } \% i}{\text{wt oxide } i} \right) \times (O \text{ in oxide } i)}{\text{formula O (24)}} \]  

(3-4)

The concentration of each cation in garnet (in moles) can be calculated utilizing this normalization:

\[ A \text{ (mol)} = \left( \frac{\text{wt } \% \text{ oxide } \times O_{norm.}}{\text{wt oxide } \times O_{norm.}} \right) \times \text{# cations in oxide} \]  

(3-5)

where A is the cation being analyzed. These values can now be used in calculating the mole fraction of the garnet endmembers (e.g. eq. 3-3) and to calibrate the grey-scale X-ray maps.

To create a composition profile plot of the garnet, a line transect across the grain must be added in an image editing program. ImageJ is a freeware program that has the capability to store grey-value data across a transect with recorded distances (in pixels). If the distance of the line is known or can be calibrated against other images (e.g. BSE), than the distance in pixels can
be converted to mm. It is recommended for the line transect to have a blending of ~5–10 pixels to allow for a smoother plot. The locations of spot analyses conducted on the garnet should have corresponding spot-analysis of the grey-value in ImageJ. A calibration curve may then be constructed (grey-scale vs. mole fraction of garnet endmember). The equation of the curve can be used to convert all grey-scale values from the transect to mole fractions. Plotting these values against distance will result in a garnet profile. Inclusions should be excluded to provide the most useful plot. Repetition of this procedure for \( X_{\text{Alm}} \), \( X_{\text{Sps}} \), \( X_{\text{Pyp}} \), \( X_{\text{Grs}} \) and \( \text{Fe/(Fe+Mg)} \) allows for compilation into one plot (e.g. Figure 3-17).

2.7.3 P-T-X contour diagrams

P-T-X contour diagrams for garnet were constructed for several samples using Program Gibbs. XRF bulk-rock compositional analysis was required. Before the diagrams can be made, the chemical system and mineral assemblages must be chosen (a “typical” pelitic schist sample uses the KFMASH system with the assemblage garnet + biotite + chlorite + muscovite + quartz + water). It is important to not use a system with an oxide component that is not present in a phase (e.g. if \( P_2O_5 \) is included, a phosphate phase should be present). Only the major phases are included, since including all of the minerals in the assemblage is time consuming and disadvantageous.

Contour plots are made through Gibbs’ method of differential thermodynamic calculation (while invoking mass balance). A plot is created for \( X_{\text{Alm}} \), \( X_{\text{Sps}} \), \( X_{\text{Pyp}} \), \( X_{\text{Grs}} \) and \( \text{Fe/(Fe+Mg)} \). The garnet profiles previously mentioned can now be used for P-T predictions.
during garnet growth. Mole fractions of the garnet species are plotted for their core and rim values (Figure 3-18). The intersection of these isopleths would result in points in $P$-$T$ space for the core and rim of the garnet. This provides a useful thermodynamic reference for the quartz being included during garnet growth. It is recommended to read Spear (1993) for a more in-depth discussion on $P$-$T$-$X$ contour diagrams and garnet analysis.

Deeply buried rocks that experienced rapid exhumation (i.e. isothermal decompression) have additional processes that must be considered, including isobaric heating durations. The possibility of extensive coeval modification of garnet chemistries must be taken into account to ensure $P$-$T$-$X$ diagrams are representative of growth conditions (Caddick et al., 2010). The depth of modification can be calculated using:

$$C_t = C_o + (C_m - C_o) \left[ 1 + 2 \sum_{n=1}^{\infty} -1^n \times exp \left( -Dn^2\pi^2 \frac{t^2}{a^2} \right) \right]$$  \hspace{1cm} (3-6)

where $C_t$ is the resultant composition of garnet at radius, $C_o$ is the initial (unmodified) composition of garnet, $C_m$ is the matrix composition (constant), $D$ is the diffusivity, and $a$ is the grain size of the crystal. A diffusion completeness can be established to express the change in compositional proportions in a phase after any time; $(C_t - C_o)/(C_m - C_o)$ (Caddick et al., 2010). Assuming peak T of 600 °C for the Strafford Dome (Menard and Spear, 1994), and the max timing for prograde metamorphism of 20 Ma (using previous $^{40}$Ar/$^{39}$Ar closure age dates on hornblende), a maximum depth of <200 µm for 0.01% diffusion completeness of modified Fe at $\text{Alm}_{0.7}\text{Pyr}_{0.2}\text{SpS}_{0.05}\text{Grs}_{0.05}$ (calculated with eq. 3-6, using Fe tracer diffusion data from Carlson, 2006; Caddick et al., 2010). Although this distance is expected to be significantly less since D$_2$ deformation produced a majority of the garnets with elevated temperatures near peak T.
conditions (~550 °C). In addition, a rim of increased Mn is expected with isobaric heating, which when observed in X-ray elemental mapping was minimal (<10 µm).
Figure 3-1. Puck prepared for SIMS analysis. A one-inch Al round is used, with target areas removed from thin sections and set in epoxy. This method of sample preparation allows for faster navigation times and less sample exchange times during analysis.

Figure 3-2. (a) Electron bombardment causes an electron movement from the valence to the conduction band, creating a hole. A photon may be emitted, with the resultant photon energy, $h\nu$, either the direct result of returning to the created hole (b), or through the association with defects and/or impurities (c) and (d). From Reed (2005).
Figure 3-3. CL imaging through various filters: (a) blue; (b) red; (c) green. Combining images from the three filters results in an RGB image (d), or no filter can be used to capture images in panchromatic light (e). Note that polish imperfections causing surface contamination are more extensive with blue and green filters (appearing as bright spots on the images). Brightness, contrast and voltage remained constant for all images.
Figure 3-4. Potential results from CL instrument problems. (a) False-brightness in garnet due to pump oil coating the mirror’s surface. (b) An off centered mirror requires imaging a smaller area to avoid capturing the mirror edge (near top of image). (c) An off-centered mirror may cause a gradient of CL intensity with brighter regions near the center of the mirror. (d) If no problems occur, a high-quality image like that shown here can be collected and is ideal for Ti distribution analysis in quartz. Note however that vertical lines are present in the quartz inclusions due to previous X-ray elemental mapping of the sample.
Figure 3-5. Ka intensity lines for elements (Z) detected by electron and wavelength dispersive spectrometers (EDS and WDS, respectfully; at 20 kV accelerating potential). TAP, PET and LiF are typical crystals used in WDS analysis. From Reed (2005).

Figure 3-6. Backscattering coefficient (η) relative to atomic number (Z). Note that in BSE imaging, phases with stoichiometric essential elements of higher Z will result in brighter BSE. From Reed (2005).
Figure 3-7. Backscattered electron (BSE) image of quartz inclusions in garnet (sample TM783). Note that garnet, which contains elements with higher atomic numbers (e.g. Fe and Al), appears brighter than the quartz essentially comprised of Si and O. Yet brighter is the ilmenite, which is mostly comprised of Fe, Ti and O.
Figure 3-8. Elemental X-ray maps of a garnet porphyroblast, analyzing for Al, Ca, Fe, Mg, Mn and Ti (sample TM783). Note the increase in Mg and the decrease in Mn from core to rim. Garnet maps may be useful in petrological studies, determining $P-T$ conditions during garnet growth and in the construction of $P-T-t-D$ histories of the rocks. The porphyroblast shown is the compilation of four individual maps for a high-resolution scan that took approximately eight hours.
Figure 3-9. Thin section elemental X-ray maps for the elements Ti (a), Fe (b), Ca (c) and Mg (d) for sample 10SD03B2. These low-resolution maps are useful for locating and identifying accessory phases present in the sample. Note that Ti phases (which are pertinent to finding to constrain activities for this project) are very distinguishable in the Ti map. Other accessory phases are very distinguished in other maps (e.g. apatite, which appears red in the Ca map). Note that in addition to locating these phases, these maps may be used for petrological observations and interpretations. For example, there is a high density of ilmenite contained as inclusions within garnet (Ti map), but few are present in the matrix. One interpretation is there was an ilmenite-consuming reaction that took place post-garnet growth.
Table 3-1. Electron Microprobe Spot Analysis Standard Calibration Results

<table>
<thead>
<tr>
<th>Standard</th>
<th>Mg</th>
<th>Al</th>
<th>Si</th>
<th>Ca</th>
<th>Ti</th>
<th>Cr</th>
<th>V</th>
<th>Mn</th>
<th>Fe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pyrope</td>
<td>1.002</td>
<td>1.003</td>
<td>1.007</td>
<td>0.205</td>
<td>0.004</td>
<td>0.001</td>
<td>0.000</td>
<td>0.004</td>
<td>0.147</td>
</tr>
<tr>
<td>Di₂Ti</td>
<td>0.975</td>
<td>0.001</td>
<td>1.474</td>
<td>1.009</td>
<td>0.018</td>
<td>0.000</td>
<td>0.001</td>
<td>0.000</td>
<td>0.001</td>
</tr>
<tr>
<td>Rutile</td>
<td>0.000</td>
<td>0.001</td>
<td>0.004</td>
<td>0.000</td>
<td>0.990</td>
<td>0.002</td>
<td>0.078</td>
<td>0.000</td>
<td>0.004</td>
</tr>
<tr>
<td>Chromite</td>
<td>0.629</td>
<td>0.374</td>
<td>-0.001</td>
<td>0.000</td>
<td>0.001</td>
<td>0.998</td>
<td>0.001</td>
<td>0.004</td>
<td>0.191</td>
</tr>
<tr>
<td>V₂O₅</td>
<td>0.001</td>
<td>0.000</td>
<td>0.000</td>
<td>0.001</td>
<td>0.000</td>
<td>0.148</td>
<td>1.004</td>
<td>0.000</td>
<td>0.001</td>
</tr>
<tr>
<td>Tephroite</td>
<td>0.012</td>
<td>-0.001</td>
<td>0.776</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.999</td>
<td>-0.035</td>
</tr>
<tr>
<td>Fayalite</td>
<td>0.003</td>
<td>0.000</td>
<td>0.729</td>
<td>0.002</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.993</td>
</tr>
</tbody>
</table>

Note: Calibration analyses are output as the ratio of measured elemental concentration divided by known standard concentrations. Bold analyses display elements measured on corresponding standard.

Figure 3-10. Schematic of instrument setup for the Cameca SIMS 1280. The mass spectrometer allows for high-resolution trace elemental analysis. From Valley and Kita (2009).
**Figure 3-11.** Illustration of bombardment of an O\(^+\) primary ion beam on the sample surface causing sputtering during SIMS analysis. Note that although many atoms are mobilized during impaction, only a very few (<<10\%) actually become measurable secondary ions. Mobilization during collision cascade is shown by the arrows. From Stern (2009).

**Figure 3-12.** SEM image of the resultant pit caused through SIMS analysis. Focused ion beam (FIB) milling was done to allow for a cross-section view of the pit and to see the volume of material loss during the analytical procedure. From Valley and Kita (2009).
Figure 3-13. Calibration curve from analyzed standards of known Ti (ppm) against the corrected $^{48}\text{Ti}/^{30}\text{Si}$. This is used to convert all isotope ratios measured to [Ti].

Figure 3-14. The atom is comprised of shells (K, $n=1$; L, $n=2$; M, $n=3$, etc.) which govern the energies associated with electron transitions between shells. Sub-shells (e.g. L$_1$) are present which result in specific characteristic spectra unique for that element. The K-shell consists of 2 electrons, the L-shell of 8, the M-shell of 18, and increasing outwards. From Reed (2005).
Figure 3-15. Characteristic X-ray energies for silver (Z=47). These energies are the difference in energy between the conduction band and the orbital the electron returns to during transition. Below, the characteristic X-ray spectra for the L-spectrum of silver is illustrated. Modified from Reed (2005).

Table 3-2. Major cation oxides with calculated weight oxides

<table>
<thead>
<tr>
<th>Cation Oxide</th>
<th>Oxide Weight (amu)</th>
<th>Cation Oxide</th>
<th>Oxide Weight (amu)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>60.086</td>
<td>MgO⁺</td>
<td>40.305</td>
</tr>
<tr>
<td>TiO₂</td>
<td>79.867</td>
<td>CaO⁺</td>
<td>56.078</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>101.964</td>
<td>MnO⁺</td>
<td>70.938</td>
</tr>
<tr>
<td>Cr₂O₃⁺</td>
<td>151.992</td>
<td>ZnO⁺</td>
<td>81.390</td>
</tr>
<tr>
<td>V₂O₅⁺</td>
<td>149.884</td>
<td>FeO⁺</td>
<td>71.845</td>
</tr>
</tbody>
</table>

†Oxides used in Al-silicate garnet mole fraction calculations
Figure 3-16. Pseudosection of the system MnNCKFMASH for the average Waterville biotite zone bulk-rock composition (Tinkham et al., 2001). Pseudosections are useful to show equilibrium mineral assemblages during metamorphism. Note that although reactions are shown in $P$-$T$ space, caution is recommended when assuming $P$-$T$ conditions based on stable phase paragenesis since pseudosections are extremely sensitive to bulk rock chemistries. Therefore, variability or mis-representative bulk compositions can change these $P$-$T$ parameters. Due to the lack of bulk-rock chemistries in samples from this study (and multiple chemistries from each sample to ensure consistency), this pseudosection was selected for analysis due to the similarities to that of the Strafford Dome.
Figure 3-17. Example garnet profile plot of $X_{\text{Alm}}$, $X_{\text{PpP}}$, $X_{\text{SpS}}$, $X_{\text{Grs}}$ and Fe/(Fe+Mg). Profile corresponds to traverse shown in Figure 3-8 (sample TM783; a=0). Note that although zoning is not evident for the Fe EDS map, subtle variations from core to rim can be expressed in the profile plot.
Figure 3-18. Contours of garnet composition for $X_{\text{Pyp}}$, $X_{\text{Alm}}$, $X_{\text{Sps}}$, and $\text{Fe/(Fe+Mg)}$ for the garnet + biotite + chlorite + plagioclase + muscovite + quartz + $\text{H}_2\text{O}$ in the system MnNCKFMASH. Ti-in-quartz isopleths (ppm; dashed lines; after Thomas et al., 2010) and $\text{Al}_2\text{SiO}_5$ stability fields (green lines; after Holdaway, 1971) are shown. Isopleths are calibrated to a fixed TiO$_2$ activity of 1. From Spear et al. (1990).


Chapter IV

Sample Analysis and Interpretations

1. Petrography, Microstructures and Analyses

1.1 TM783

Sample TM783 is a garnet-kyanite schist with the assemblage garnet + kyanite + quartz + K-feldspar + biotite + muscovite + ilmenite + tourmaline ± plagioclase ± rutile ± opaques ± zircon (Table 4-1). Because this sample is part of the Menard RPI collection (Menard, 1991), no structural data or orientation is available. However, nearby localities (e.g. sample 10SD03) were visited and can place this sample in a general structural framework. The matrix contains asymmetric crenulation cleavage, with the foliation defined by compositional layering and preferred orientation of micas. There are gradational transitions between cleavage domains (composed of biotite, muscovite, kyanite and tourmaline) and microlithons, with smooth, parallel-anastomosing cleavage domains present. Larger biotite grains overgrow the matrix with no deflection of the surrounding foliation. Undulose extinction in quartz is common. Quartz domains (including K-feldspar and plagioclase) contain grains that often display foam textures (grain boundaries at 120° triple junctions). Chemical zoning of tourmaline in the sample is evident in thin section. The sample contains numerous, large (up to ~12 mm) garnet
porphyroblasts with spiral inclusion trails (Figure 4-1) and smaller porphyroblasts with linear inclusion trails (Figure 4-2; Table 4-2). The included linear trails define an internal foliation, $S_i$, that is oblique to the matrix foliation, $S_e$. Ilmenite grains in the sample are largely limited to inclusions in the garnet porphyroblasts (Figure 4-3). This is true for rutile as well, although ilmenite is significantly more abundant. A large snowball garnet was selected for further analysis.

The garnet contains a spiral inclusion trail, with linear inclusion trails on the “top” and “bottom” of the garnet (Figure 4-1). The inclusion trails extend continuously into the external foliation, with crenulation cleavage preserved near the center of the grain. Kyanite is partially included near the rim of the garnet. X-ray mapping of the porphyroblast shows a notable decrease in Mn and an increase in Mg from core to rim (Figures 4-4 and 4-5; Table 4-3). CL imaging was conducted for various regions throughout the porphyroblast, with SIMS analysis focused on quartz from the core and rim of the garnet, and the surrounding matrix. Quartz inclusions typically contain dark cores and brighter rims in CL (Figure 4-6a), with matrix grains sometimes consisting primarily of the bright rim (entirely bright grains). Bright, linear bands are often present that cross-cut the inclusions (Figure 4-6c). Some inclusions display brecciated textures in CL (Figure 4-6d). Foam textures between neighboring quartz grains is sometimes observed in polycrystalline quartz inclusions.

Inclusions in the porphyroblast’s core contain dark cores with $[\text{Ti}]$ of $\sim 3.7 \pm 0.1$ ppm and bright rims up to $5.5 \pm 0.2$ ppm (Appendix C; Table 4-4). Quartz from the core, rim and linear inclusion trails in the garnet all contain similar Ti concentrations. Matrix material records similar
Ti in quartz cores (~3.8 ± 0.1 ppm) but have bright rims that contain significantly higher [Ti] (up to 7.8 ± 0.2 ppm).

1.2 09SD08A

Sample 09SD08A is a garnet schist with the assemblage garnet + quartz + K-feldspar + biotite + muscovite + rutile ± ilmenite ± apatite ± sphene ± zircon ± opaques (Table 4-1). The thin section was cut perpendicular to the foliation and parallel to the dip direction. Field measurements of the dominant foliation were 298°, 53° (dip-azimuth, dip), with a weak mineral lineation along 263°, 44° (trend, plunge; Figure 4-7). The matrix contains a horizontal slaty schistosity that appears slightly crenulated in areas, with the foliation defined by compositional layering and the preferred orientation of micas and opaques. When present, the crenulations are observed in rough, parallel disjunctive cleavage domains. There is a relatively small volume of cleavage domains present (<5–10%) that consists of biotite + muscovite + ilmenite. Quartz domains (including K-feldspar) contain grains that often display foam textures. The thin section contains several garnets 3–4 mm in diameter with linear inclusion trails (primarily quartz and ilmenite) that have an oblique orientation to the matrix foliation (φ up to 35° is typical; Figure 4-8). The garnets typically have strain shadows consisting of quartz, K-feldspar and mica. Coarse-grained quartz veins cut through the sample and are concordant with the foliation. A garnet and representative spots from the matrix and quartz vein were selected for further analysis.

X-ray maps of garnet in 09SD08A display a decrease in Mn from core to rim, with a very thin (<10 µm) bright rim in Mn maps that surrounds the grain (Figures 4-9 and 4-10). Other
elements (e.g. Ca, Fe and Mg) are (for the most part) homogeneous throughout the grain (Table 4-3). CL images of quartz from the core and rim of the garnet, and from the pressure shadow, were collected. Inclusions commonly contain dark quartz with thin, bright rims surrounding them (Figure 4-6a). Bright, linear features (in CL) are occasionally observed in inclusion grains. Quartz grains in the pressure shadows have bright rims that are much more extensive, with some grains that are uniformly bright in CL (Figure 4-6e).

The matrix sample selected for analysis contains a larger, ribbon quartz grain and finer grained quartz. In CL, quartz grains typically show a dark core that grades to a brighter rim. On some grains, a sharp contact with a second dark region on the rim is observed, which forms a foam texture with the surrounding grains (Figure 4-6b). The larger quartz grain is more homogeneous in brightness, although it contains several strips of dark domains that taper to the left side of the image. Quartz from the vein in the sample is homogeneous in CL.

Inclusions from the porphyroblast’s core contain dark cores with [Ti] of 2.6–3.6 ± 0.4 ppm and narrow bright rims (<5 µm) that were too thin to analyze with the SIMS (Appendix C; Table 4-4). Similar concentrations were observed for grains in the core and rim of the porphyroblast. The bright, linear features occasionally form clusters with higher [Ti] (8.4 ± 0.4 ppm). The pressure shadow contains similar dark cores (~3.7 ± 0.4 ppm), although the bright rims are higher in Ti; up to 9.8 ± 0.3 ppm. The matrix quartz contains dark cores that grade to brighter rims from 4.8–9.2 ± 0.3 ppm. The dark rim that forms the foam texture with surrounding grains has [Ti] of 6.7 ± 0.3 ppm. The quartz vein contains a homogeneous [Ti] of 3.4 ± 0.2 ppm.
1.3 TM455

Sample TM455 is a garnet schist with the assemblage garnet + quartz + K-feldspar + biotite + muscovite + rutile + ilmenite + magnetite (Table 4-1). Because this sample is part of the Menard RPI collection (Menard, 1991), no structural data or orientation is available, although this site was visited and structural data was collected (e.g. 09SD08 and 10SD01A). The matrix contains asymmetric crenulation cleavage, with the foliation defined by compositional layering and preferred orientation of micas. Pressure solution seams are present in micaceous domains (composed of muscovite + biotite + ilmenite) and define the microlithons. Highly-crenulated quartz veins are present in the sample, with extensive subgrain rotation recrystallization occurring (Figure 4-11) resulting in ribbon quartz grains with adjacent subgrains that form an oblique foliation at a low angle relative to the ribbon grain. Two types of garnet are present within the sample: numerous small (sub-mm) inclusion-free grains (in micaceous domains) and larger (up to 2 mm) porphyroblasts that preserve a crenulation cleavage defined by quartz and ilmenite inclusions present in more quartz-rich domains (Figure 4-12). A garnet with an internal crenulation cleavage and a sample of the recrystallized quartz vein (including ribbon and subgrains) were selected for further analysis.

X-ray mapping of the garnet porphyroblast showed the grain to be fairly chemically homogeneous, except for a distinct rim that contains a significant increase in Ca and a decrease in Mn (Figures 4-13 and 4-14). CL imaging of quartz inclusions within the porphyroblast displays grains with dark cores (down to 2.8 ± 0.3 ppm Ti; Appendix C; Table 4-4), occasionally with patchy zoning (brighter regions up to 5.1 ± 0.3 ppm Ti), and thin (<5 µm) bright rims (Figure 4-
6a). [Ti] analysis of the recrystallized quartz vein resulted in Ti measurements of \(\sim 4.8 \pm 0.4\) ppm for the ribbon grains, with lower [Ti] for the subgrains \(\sim 3.6 \pm 0.5\) ppm; Figure 4-6f).

1.4 TM623

Sample 09SD08A is a highly crenulated garnet schist with the assemblage garnet + quartz + K-feldspar + biotite + muscovite + ilmenite + magnetite + rutile ± apatite ± zircon ± opaques (Table 4-1). Because this sample is part of the Menard RPI collection (Menard, 1991), no structural data or orientation is available, although nearby outcrops were visited (10SD02A and B) and with structural data was collected for them. The foliation in the sample is defined by compositional layering, preferred orientation of micas and ilmenite, and by grain size variation. Cleavage domain volume varies widely, with larger volumes associated with little to no quartz or fine-grained quartz, and lower volumes (<15%) corresponding with coarser grained quartz. Crenulations tend to be parallel-anastomosing and asymmetric. The sample contains a crenulated quartz vein that separates a quartz-rich domain from a mica-rich domain (Figure 4-15). Microlithons are defined by pressure solution seams present in the micaceous domains. Rare kink-banding is present and nearly perpendicular to the crenulations throughout the sample. Garnet porphyroblasts have rare inclusions, but when present, these inclusions are so large that specific foliations cannot be interpreted by inclusion trail analysis. Biotite porphyroblasts have random orientations relative to the matrix foliation and typically have a poikiloblastic texture when grown in domains with quartz present. A portion of the crenulated matrix with quartz present was selected for further analysis.
CL imaging of the matrix quartz shows homogeneous dark grains ([Ti] down to 2.2 ± 0.2 ppm; Appendix C; Table 4-4) with very narrow (<5 µm) rims. Local bright regions are present, and contain higher [Ti] (~5.6 ± 0.2 ppm).

1.5 10SD03B2

Sample 10SD03B2 is a garnet-amphibole schist with the assemblage garnet + amphibole + quartz + K-feldspar + biotite + muscovite + ilmenite ± opaques ± zircon (Table 4-1). Since the “outcrop” could not be confidently determined to be in-situ, no structural orientation data could be collected. The matrix contains asymmetric crenulation cleavage, with the foliation defined by compositional layering and preferred orientation of micas. There are gradational transitions between cleavage domains (composed of biotite, muscovite and amphibole; ~40% mica domains) and microlithons, with smooth, parallel-anastomosing cleavage domains present. Larger biotite grains overgrow the matrix with no deflection of the surrounding foliation. Quartz domains (including K-feldspar) contain grains that often display foam textures. The sample contains numerous, large (up to ~12 mm) garnet porphyroblasts with spiral inclusion trails (Figure 4-16; Table 4-2). Ilmenite grains in the sample are largely limited to inclusions in the garnet porphyroblasts (Figure 4-3). A large snowball garnet was selected for further analysis.

The garnet contains a spiral inclusion trail, with linear inclusion trails on the sides of the garnet (parallel to the matrix foliation; Figure 4-16). The inclusion trails extends continuously into the external foliation, with crenulation cleavage near the center of the grain. X-ray mapping of the porphyroblast shows a notable decrease in Mn and an increase in Mg from core
to rim (Figures 4-17 and 4-18; Table 4-3). CL imaging was conducted for various regions throughout the porphyroblast, with SIMS analysis focused on quartz from the core and rim of the garnet, and the more linear inclusion trails present. Quartz inclusions typically contain brighter rims in CL, although, unlike TM783, there is a mixture of grains dominantly dark and bright (in CL) present. In the linear inclusion trails, more bright planar features are present in the inclusions than is present in the core and rim of the porphyroblast (Figure 4-6c). Foam textures between neighboring quartz grains is sometimes observed in polycrystalline quartz inclusions.

Inclusions from the porphyroblast’s core contains dark regions with [Ti] down to 4.8 ± 0.6 ppm; brighter regions reach 7.8 ± 0.6 ppm Ti (Appendix C; Table 4-4). The quartz rim has higher [Ti] than the core, with dark regions down to 5.8 ± 0.4 ppm Ti and brighter regions up to 9.7 ± 0.5 ppm Ti. The linear inclusion trails, however, have [Ti] very similar to that observed near the core of the grain.

1.6 10SD03D

Sample 10SD03D is a garnet-kyanite schist with the assemblage garnet + kyanite + quartz + K-feldspar + biotite + muscovite + ilmenite ± apatite ± zircon ± opaques (Table 4-1). The thin section was cut perpendicular to the foliation and parallel to the dip direction. Field measurements of the dominant foliation were 049°, 28° (dip-azimuth, dip; Figure 4-7). The matrix contains a slaty cleavage with the foliation defined by compositional layering and preferred orientation of micas and kyanite. Approximately 40% of the sample is micaceous
domains (biotite + muscovite + kyanite + opaques). Quartz domains (including K-feldspar) contain grains that often display foam textures. The sample contains several garnets 3–4 mm in diameter with linear inclusion trails (primarily quartz and ilmenite) that are continuous with \( S_e \) (Figure 4-19). Coarse-grained quartz veins cut through the sample along the foliation. A garnet with a linear inclusion trail was selected for further analysis.

Garnets in 10SD03D are chemically homogeneous, except for a slight increase in Mn that appears to spiral throughout the grain, cross cutting the included foliation (Figures 4-20 and 4-21). CL images of quartz inclusions throughout the grain typically display dark cores and bright rims (Figure 4-6a). Quartz from inclusions and matrix material have similar dark cores [Ti], down to 3.0 ± 0.3 ppm Ti (Appendix C; Table 4-4). The rims in the inclusions have [Ti] up to 8.6 ± 0.3 ppm, whereas the bright rims present in the matrix only reach 6.6 ± 0.3 ppm.

2. Sample Interpretations

2.1 TM783

Structural data were compiled from nearby outcrops to where TM783 was collected (see 10SD03, Figure 4-7). The \( S_1 \) and \( S_2 \) schistosities have been folded, with a great circle plotted to predict the fold hinge orientation. Results show a NNE-plunging fold hinge with lineations and measured fold hinges in the field plotting around the predicted hinge. These results compare very similarly to previous results recorded (Figure 4-22, DIV).
Crenulation development in the sample forms the $S_2$ schistosity, deformed during $D_2$. Garnet growth was syn-kinematic with $D_2$, with growth in response to significant pressure increases (pressures range from $\sim$6–8.4 kbar, around 565 °C; Table 4-5; Figure 4-25). Static recrystallization at elevated $P$-$T$ conditions caused the polygonization of quartz in the sample. An ilmenite-consuming reaction occurred post-garnet growth (inferred from the abundance of ilmenite present as inclusions, but the lack of the phase in the matrix). It is important to note that reactions involving phases of Ti-essential stoichiometric components must be recognized for Ti activity changes may result from such reactions (e.g. a rutile-out, ilmenite-in reaction). Possible reactions and the implications will be further discussed in Chapter V.

Dark cores in quartz are inferred to be relics of early prograde recrystallization or from the rock’s protolith. It is most likely preserving early prograde since the protoliths are pelites that eroded from igneous and metamorphic sources and would have variable [Ti] retained within their quartz grains. Bright rims in the porphyroblast represent Acadian re-equilibration attributed to a kyanite-in reaction and are pre-kinematic relative to snowball garnet growth (determined by constant [Ti] in quartz inclusions throughout the grain). $P$-$T$ conditions associated with the end of $D_1$ (7 kbar, 450 °C at $a_{TiO_2} \approx 1$; Menard and Spear, 1994) would result in similar [Ti] to these rims, and is probably the timing of quartz recrystallization that produced the bright rims observed in garnet inclusions. The higher [Ti] present in the matrix grains represents re-equilibration/recrystallization at peak pressure conditions from $D_2$ deformation. TitaniQ calculations suggest matrix quartz to have been recrystallized at $\sim$8.5 kbar and $\sim$525 °C ($a_{TiO_2} = 0.9$ was used to account for lower activities resulting from the presence of ilmenite,
rather than rutile, remaining in accordance with Ghent and Stout’s (1984) findings previously discussed).

2.2 09SD08A

Structural data were compiled for 09SD08A (see 09SD08A, Figure 4-7). The $S_1$ schistosity has been folded, with a great circle plotted to predict the fold hinge orientation. Results show a W-plunging fold hinge with lineations and measured fold hinges in the field plotting around the predicted hinge. This sample is located on the western flank of the dome and reflects the plunging of the rocks from the core of the dome (as a result of the doming event; Figures 4-22 through 4-24).

Garnet porphyroblast growth was inter-tectonic with respect to $D_1$ and $D_2$, with $S_1$ schistosity preserved as the internal foliation. Pressure shadows formed on the grain as a result of inhomogeneous strain in the sample due to the rigidity of the porphyroblast relative to the groundmass. Zoning in garnet suggests growth during fairly constant $P$-$T$ conditions (~7 kbar, 540 °C; Figure 4-27). The bright garnet rim (Mn X-ray maps) is attributed to higher T conditions, likely during the early stages of exhumation causing modification of the garnet rim (Caddick et al., 2010), although this modification is minimal. The dark cores present in the majority of quartz grains are similar to that observed in TM783, and most likely represent an early prograde recrystallization, or are relics of the protolith. The thin bright rims are probably attributed to diffusion of Ti from the garnet, post-inclusion (Spear and Wark, 2009). The bright linear features in quartz inclusions in garnet are probably planar defects. The higher [Ti] observed in these
defects may represent quartz trying to minimize strain during static recrystallization, re-equilibrating under higher temperatures after D₁ deformation and prior to being included. The thermobarometer probably doesn’t apply to these high-defect zones where more Ti sites may be present and interpretation of these analyses should be cautioned. Quartz rims in the pressure shadows contain [Ti] that are higher than noted in TM783, which is attributed to the sample locations within the Strafford Dome. 09SD08A is closer to the core of the dome, which experienced elevated temperatures relative to samples further away (Menard and Spear, 1994). This probably still reflects quartz recrystallization at peak P for D₂. The darker rims observed in matrix quartz may be the result of a quartz-producing reaction that caused a secondary growth rim on the grains. A reaction rim is preferred over re-equilibration during static recrystallization because of the sharp contact the dark rim has with the interior of the grain (whereas re-equilibration would produce a gradient). This reaction could have occurred at higher P or lower T to account for the lower [Ti]. The foam texture suggests extensive static recrystallization during the growth of this rim.

The darker streaks observed in the larger quartz grain may be a result of polishing after electron-beam analysis of the sample. In the CL image (Figure 4-6b), a false-bright box from BSE imaging is observed. Post-imaging polishing removes the top layers of atoms on the sample, which removes any electron beam damage. The Al-rounds the samples are prepared in typically have a rim that protrudes above the sample surface. Due to this occurrence, a high-quality polishing of the sample surface was difficult to achieve and may attribute to the streaking observed.
2.3 TM455

Structural data were compiled from outcrops near where TM455 was collected (see 09SD08, Figure 4-7). The S₁ schistosity has been folded, with a great circle plotted to predict the fold hinge orientation. Results show a NW plunging fold hinge with lineations and measured fold hinges in the field plotting around the predicted hinge. Crenulations were observed in outcrop, but no structural measurements from them could be obtained.

The crenulations present in the sample were formed during D₂ (creating an S₂ schistosity). The quartz vein was present pre-D₂ and was affected by this deformation event. Garnet porphyroblast growth (with inclusions present) was syn-tectonic with D₂ (with crenulated S₁ included). It is difficult to determine the relative timing of growth of the numerous, small inclusion-free garnet grains for there are no inclusion trails present to interpret. Compositional profiles that show increased Ca (and decreased Mn) suggests that pressure increase (5.7 to 6.2 kbar) and temperature decreased (520 to 510 °C) between the two stages of growth (Figure 4-26). The dark cores present in the majority of the quartz grains are similar to that observed in many other samples and represents early prograde or protolith conditions. The bright regions (CL) present in the quartz inclusions have [Ti] similar to that in other samples that contain quartz regions recrystallized at the end of D₁. The thin bright rims are probably attributed to diffusion of Ti from the garnet post-inclusion. The ribbon grains present in the quartz veins have similar [Ti], and the lower [Ti] in subgrains could represent recrystallization during higher P conditions during the end of D₂. Although because much is still not known about the application of the TitaniQ thermobarometer to quartz veins (e.g. activity
constraints on the veins during formation and the effective diffusion distance of Ti for the vein), such conclusions are cautioned.

2.4 TM623

Structural data were compiled from outcrops near where TM783 was collected (see 09SD03, Figure 4-7). The S₁ schistosity has been folded, with a great circle plotted to predict the fold hinge orientation. Results show a NNE plunging fold hinge with lineations, measured in the field plotting around the predicted hinge. These results are similar to results recorded previously (Figure 4-22, DV). Crenulations were observed in outcrop, but no structural measurements were obtained.

The crenulations present in the sample were formed during D₂ (creating an S₂ schistosity). Kink banding, when present, defines the S₂ schistosity. The dark cores observed in CL for a majority of the quartz grains are similar (albeit slightly lower [Ti]) to the other samples and are relic of early prograde metamorphism or of protolith conditions. [Ti] for the bright regions are significantly lower than previously recognized in other samples. The reason for this is due to the decreased temperatures experienced during peak metamorphism east of the dome. Menard and Spear (1994) recognized that peak temperatures reached in the area are 540 °C near the Richardson Memorial Contact, ~600 °C in the dome’s core, but are <400 °C on the eastern side of the dome when approaching the Monroe Fault.
2.5 10SD03B2

Garnet porphyroblast growth was syn-tectonic with D2. Zoning in garnet suggests a growth during increased P and fairly constant T (6.5–8.5 kbar, 560 °C; Figure 4-28). An ilmenite-consuming reaction occurred post-garnet growth (inferred from the abundance of ilmenite present as inclusions, but the lack of the phase in the matrix). The structural data discussed for sample TM783 are applicable to 1SD03B2 due to the proximity of the two samples to each other.

Dark regions (CL) in inclusions from the garnet core have [Ti] more similar to that observed at the end of D1, although, because patchy zoning is occasionally present, Ti redistribution could result in higher-than-expected [Ti] in an attempt at rehomogenization. Brightness in CL increases significantly from core to rim, which again may be attributed to patchy zoning, or may suggest temperature increase during growth (and the inclusion of quartz) that would re-equilibrate grains at slightly higher [Ti]. This latter assumption is probably false since the inferred P-T path during garnet growth (syn-tectonic) suggests significant pressure increase; this suggests [Ti] fluctuation is attributed to patchy zoning. Another important note to make is the increased uncertainty measured during SIMS analysis of this sample relative to others. This is attributed to poor-focusing of the ion beam, which causes bombardment over a larger region, with longer dwell times required to remove surface contamination. Bright rims present in the inclusion grains are the result of diffusion of Ti from garnet after being included.
2.6 10SD03D

The structural data discussed for sample TM783 are applicable to 1SD03D due to the proximity of the two samples to each other. Garnet porphyroblast growth was post-tectonic with respect to D1 (which produced the S1 schistosity). The homogeneous chemical composition confirms this interpretation, except for the apparent annulus present in Mn X-ray maps (only minor compositional differences relative to the majority of the porphyroblast). The implications of this anomaly are unknown. Pressure and temperature during growth were ~6.5 kbar and 565 °C (Figure 4-29). In addition to the chemical zoning and inclusion trail interpretation, the zoning and chemistry of quartz grains also suggest post-tectonic growth. Inclusions from the core and matrix have similar core [Ti], down to 3.0 ppm. This is most likely the result of early prograde recrystallization or is inherited from the protolith.
Table 4-1. Sample Locations and Mineralogy

<table>
<thead>
<tr>
<th>Sample Name</th>
<th>UTM Coordinates†</th>
<th>Mineralogy</th>
<th>Quartz Abundance</th>
<th>Zone</th>
<th>Rock Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1  TM485</td>
<td>4852793.0</td>
<td>Quartz + feldspar + muscovite ± opaques</td>
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<td>Quartz phyllite</td>
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<td>2  TM551</td>
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<td>Quartz-mica phyllite</td>
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<td>4849833.0</td>
<td>Quartz + biotite + feldspar + ilmenite + rutile + zircon</td>
<td>abundant</td>
<td>Garnet</td>
<td>Quartz-mica phyllite/schist</td>
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<td>Garnet schist</td>
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</table>

Note: Numbers in left column (1-13) correspond to sample locations in Figure 2-6.
†UTM Zone: 43T; ‡Samples selected for further analysis.
<table>
<thead>
<tr>
<th>Sample Name</th>
<th>UTM Coordinates†</th>
<th>Mineralogy</th>
<th>Quartz Abundance</th>
<th>Zone</th>
<th>Rock Type</th>
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<td>Garnet gneiss</td>
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<td>Garnet-kyanite schist</td>
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<td>Kyanite + garnet + quartz + K-feldspar + biotite + muscovite + ilmenite ± opaques ± zircon abundant</td>
<td>Staurolite</td>
<td>Garnet-kyanite schist</td>
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Note: Numbers in left column (1-13) correspond to sample locations in Figure 2-6.
†UTM Zone: 43T; ‡Samples selected for further analysis.
Figure 4-1. Large (~12 mm) garnet porphyroblast from sample TM783 with spiral inclusion trail for an internal foliation ($S_i$) that continuously extends to the external matrix foliation ($S_e$). More linear inclusion trails are found at the top and bottom of the grain (arrows). Growth was syn-tectonic with $D_2$ deformation. Inclusions are primarily quartz and ilmenite. Garnet growth is at the expense of micas and kyanite. Boxes show locations of SIMS analyses.
Figure 4-2. Garnet porphyroblast with a linear S_i at an oblique angle to S_e (sample TM783). Growth was inter-tectonic with D_1 and D_2 deformation (with inclusions containing quartz from D_1 deformation).

Table 4-2. Microstructure Summary of Samples

<table>
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<tr>
<th>Sample Name</th>
<th>Qtz. Recrys. Mechanism†</th>
<th>Included Foliation in Grt (S_i)</th>
<th>Grt Growth Relative to Deformation‡</th>
<th>Quartz Occurrence</th>
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<td>D_1&lt;P&lt;D_2 or D_2⊃P</td>
<td>Matrix, inclusion, vein (post-tectonic)</td>
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<td>S_1</td>
<td>D_1&lt;P&lt;D_2</td>
<td>Matrix, inclusion, vein (post-tectonic)</td>
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<td>SGR</td>
<td>S_1; S_2</td>
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<td>D_2⊃P</td>
<td>Matrix, inclusion</td>
</tr>
<tr>
<td>10SD03D</td>
<td>Static</td>
<td>S_1</td>
<td>D_1&lt;P</td>
<td>Matrix, inclusion, vein (post-tectonic)</td>
</tr>
</tbody>
</table>

Note: Numbers in left column correspond to sample locations in Figure 2.
†SGR: subgrain rotation recrystallization.
‡⊃: syn-tectonic; P: porphyroblast growth.
Figure 4-3. Ti X-ray element maps for (a) a quarter thin section scan and (b) the snowball garnet for sample TM783. Bright spots observed in the porphyroblasts for both maps correlate to ilmenite grains. Note the high density of ilmenite present as inclusions in garnet compared to the amount present in the matrix. An ilmenite-consuming reaction must have taken place post-garnet growth to cause for this occurrence.
Figure 4-4. X-ray elemental maps of garnet for sample TM783 showing a decrease in Mn and an increase in Mg from core to rim. Profile plot (Figure 4-11) is from a to a’. Secondary growth results in increased Ca (decreased Mn) around the rim.
Figure 4-5. Garnet profile of snowball garnet from sample TM783 (a = 0 mm). Note the increase in Mg and decrease in Mn from core to rim.
Table 4.3. Electron microprobe analysis of garnets (in wt %)

<table>
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<tr>
<th>Sample:</th>
<th>09SD08A</th>
<th>09SD08A</th>
<th>TM455</th>
<th>TM455</th>
<th>TM783</th>
<th>TM783</th>
<th>TM783</th>
</tr>
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<tr>
<td>location (n)</td>
<td>rim (5)</td>
<td>core (5)</td>
<td>rim† (7)</td>
<td>core (5)</td>
<td>rim (5)</td>
<td>mantle‡ (5)</td>
<td>core (5)</td>
</tr>
<tr>
<td>Diameter</td>
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<td>2.3 mm</td>
<td>11.5 mm</td>
<td>11.5 mm</td>
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<td></td>
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</tr>
<tr>
<td>SiO₂</td>
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<td>37.64</td>
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<tr>
<td>TiO₂</td>
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<td>0.14</td>
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<td>0.07</td>
<td>0.05</td>
<td>0.04</td>
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<tr>
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<tr>
<td>Cr₂O₃</td>
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<td>0.02</td>
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<td>2.34</td>
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<td>0.00</td>
<td>0.00</td>
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<td>24</td>
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<td>0.001</td>
<td>0.003</td>
<td>0.003</td>
<td>0.003</td>
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<tr>
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<td>0.091</td>
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<tr>
<td>X_sps</td>
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<td>0.081</td>
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<td>0.043</td>
<td>0.043</td>
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<tr>
<td>X_grs</td>
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<td>0.104</td>
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<td>0.814</td>
<td>0.866</td>
<td>0.877</td>
<td>0.881</td>
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Notes: X_alm = Fe²⁺/FMCMnZCrV; X_prp = Mg/ FMCMnZCrV; X_sps = Mn/ FMCMnZCrV; X_grs = Ca/ FMCMnZCrV; FMCMnZCrV = Fe²⁺ + Mg + Ca + Mn + Zn + Cr + V. b.d.—element below the detection limit, not used for mineral formula calculation; apfu—atoms per formula unit.
†From a second generation growth of garnet on the rim of the main garnet.
‡Data collected from region between the rim and the core.
<table>
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<th>10SD03D</th>
<th>10SD03B2</th>
<th>10SD03B2</th>
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<td>core (6)</td>
<td>rim (6)</td>
<td>mantle† (6)</td>
<td>core (6)</td>
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<td><strong>Fe</strong></td>
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<tr>
<td><strong>Cr</strong></td>
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<td>0.003</td>
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<td><strong>Ca</strong></td>
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<tr>
<td><strong>Mn</strong></td>
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<td><strong>Fe²⁺</strong></td>
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<td>4.465</td>
<td>4.496</td>
<td>4.173</td>
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<tr>
<td><strong>Zn</strong></td>
<td><strong>Sum</strong></td>
<td>16.106</td>
<td>16.057</td>
<td>16.246</td>
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<tr>
<td><strong>Xₘₐₙ</strong></td>
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<td>0.722</td>
<td>0.734</td>
<td>0.681</td>
</tr>
<tr>
<td><strong>Xₚₑₙ</strong></td>
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<td>0.112</td>
<td>0.121</td>
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<td><strong>Xₕᵣₛ</strong></td>
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<td>0.089</td>
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<td>0.105</td>
</tr>
<tr>
<td><strong>Fe/(Fe+Mg)</strong></td>
<td>0.851</td>
<td>0.865</td>
<td>0.856</td>
<td>0.881</td>
<td>0.823</td>
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</table>

Notes: $X_{ₘₐₙ}$ = Fe⁺⁺/FMCMnZCrV; $X_{ₚₑₙ}$ = Mg/ FMCMnZCrV; $X_{ₚₛ}$ = Mn/ FMCMnZCrV; $X_{ₕᵣₛ}$ = Ca/ FMCMnZCrV; FMCMnZCrV = Fe⁺⁺ + Mg + Ca + Mn + Zn + Cr + V. b.d.—element below the detection limit, not used for mineral formula calculation; apfu—atoms per formula unit.

†Data collected from region between the rim and the core.
Figure 4-6. Summary blue λ CL images of quartz in various microstructural settings displaying different Ti-distribution patterns. Additional CL images and locations of images within the samples can be found in Appendix B. (a) Quartz inclusions in garnet with narrow, bright rims (possibly resulting from Ti diffusion from garnet into quartz; sample 09SD08A). (b) Matrix quartz that display typical dark core and bright rims, but with an additional dark rim that forms a sharp contact with the other zoning present in the grain (sample 09SD08A). Secondary growth resulting from a quartz-producing reaction can be the cause of this rim. (c) Quartz inclusion in garnet with bright linear features, attributed to planar defects present in the quartz lattice (sample TM783). (d) Quartz inclusion in garnet with a brecciate appearance (sample TM783). (e) Matrix quartz with significantly larger bright grain boundaries present than typically observed in inclusions (sample TM783). In some grains, the dark cores are completely “replaced.” (f) Deformed quartz vein exhibiting subgrain rotation recrystallization (sample TM455). The newly formed subgrains (darker) form an oblique foliation to the ribbon grain (brighter, massive). Image widths are ~800–900 μm.
### Table 4-4. Ti summary table

<table>
<thead>
<tr>
<th>Sample</th>
<th>Quartz Setting</th>
<th>Location in Quartz</th>
<th>Ti (ppm)</th>
<th>Std. Dev.</th>
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<tr>
<td></td>
<td></td>
<td>Rim</td>
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<td>Matrix</td>
<td>Core</td>
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<td>0.2</td>
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<tr>
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<td></td>
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<td>Rim</td>
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<td>0.3</td>
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<td>Matrix</td>
<td>Core</td>
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<td>Mantle</td>
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<td>Core</td>
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<tr>
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<td></td>
<td>Rim</td>
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<td>0.3</td>
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</table>

†A vein that was deformed and preserves subgrain rotation recrystallization (SGR), determined by ribbon grains with surrounding subgrains that form an oblique angle to the ribbon grain.

*Note: [Ti] listed for each sample is the typical (average) for that location (see Appendices B and C for more comprehensive [Ti]).*
Figure 4-7. Equal-area π-diagrams for various samples in the Strafford Dome. North to top of page. All diagrams (except second 10SD03) have poles to bedding (or bedding parallel schistosity) plotted with a cylindrical best fit (red) inserted. When present, fold axes (green) and mineral/intersection lineations (pink) were plotted. Note close fit of the measured fold axes to the cylindrical best fit of the folded $S_1$, suggesting reliable measurements.
Figure 4-8. Photomicrograph of sample 09SD08A in cross-polarized light. Garnet porphyroblasts have linear inclusion trails ($S_i$) of $S_1$ that are rotated relative to the external foliation ($S_e$) at an oblique angle. Pressure shadows developed in response to inhomogeneous strain (due to the rigidity of the garnet porphyroblasts) applied to the sample. $X$-direction of cut is in the down-dip direction.
Figure 4-9. X-ray elemental maps of garnet for sample 09SD08A showing a decrease in Mn from core to rim and patchy Ca dispersed throughout. Profile plot (Figure 4-14) is from a to a’.
Figure 4-10. Garnet profile of garnet porphyroblast from sample 09SD08A (a = 0 mm). Note the decrease in Mn from core to rim.
Figure 4-11. Photomicrograph of sample TM455 in cross-polarized light. Crenulated quartz veins are present within the sample, with ribbon quartz and subgrains present as a result of subgrain rotation recrystallization. Also present are numerous, small inclusion-less garnets (black dots scattered around the quartz vein). Garnet growth was the result of high nucleation rates and low growth rates. Box shows location of SIMS analyses.
Figure 4-12. Photomicrograph of sample TM45S in cross-polarized light. Larger porphyroblasts with inclusions present contain crenulated inclusion trails and grew syntectonically with D$_2$. Inclusions are primarily quartz and ilmenite. Boxes show location of SIMS analyses.
Figure 4-13. X-ray elemental maps of a garnet from sample TM455 showing fairly homogeneous (albeit patchy) chemistries throughout. Note increased Ca (decreased Mn) in the bottom-right rim. Profile plot (Figure 4-17) is from a to a’.
Figure 4-14. Garnet profile of snowball garnet from sample TM455 (a = 0 mm). Note the increase in Ca and decrease in Mn near the rim.
Figure 4-15. Montage photomicrograph along the length of the thin section for sample TM623 (non-oriented; cross-polarized light). A transition from right to left across the photomicrograph shows graded bedding ($S_0$) with fining left (from coarse quartz to mica). A bedding parallel ($S_1$) slaty cleavage is defined by mica, which has been crenulated during the D$_2$ deformation event ($S_2$). In the mica-rich domain to the left, a late stage kink banding ($S_3$) is seen contained within the microlithon defined by $S_2$. Large biotite porphyroblasts with random orientation to foliation are from retrograde metamorphism (post $S_0$-$S_2$). Mineral abbreviations from Kretz (1983).
Figure 4-16. Photomicrograph of sample 10SD03B2 in cross-polarized light. Garnet porphyroblast with crenulated, spiral \( S_i \) that extends continuously with the matrix foliation \( (S_e) \). The inclusion trails are more linear on the flanks of the grain (arrows). Growth was syn-tectonic with \( D_2 \) deformation. Inclusions are primarily quartz and ilmenite. Boxes show locations of SIMS analyses.
Figure 4-17. X-ray elemental maps of garnet for sample 10SD03B2 showing a decrease in Mn and an increase in Mg from core to rim. Profile plot (Figure 4-20) is from a to a'. Secondary growth results in increased Ca (decreased Mn) around the rim.
Figure 4-18. Garnet profile of snowball garnet from sample 10SD03B2 (a = 0 mm). Note the increase in Mg and decrease in Mn from core to rim.
Figure 4-19. Photomicrograph of sample 10S03D in cross-polarized light. Garnet porphyroblast with linear inclusions trails that extends continuously with $S_n$. Garnet growth is post-kinematic. Inclusions are primarily quartz and ilmenite. Rectangular box shows traverse of inclusions SIMS analyses were conducted along.
Figure 4-20. X-ray elemental maps of garnet for sample 10SD03D showing a slightly increased annulus of Mn that cross-cuts $S_p$. Profile plot (Figure 4-23) is from a to a'.
Figure 4-21. Garnet profile of snowball garnet from sample 10S03D (a = 0 mm). Note the increase in Mn in locations where the line transect crosses the “spiral.”
Figure 4-22. Simplified geological map denoting local formations and structural domains (Howard, 1969). Stereographic projects (equal area π-diagrams) associated with each domain can be found in Figures 4-23 and 4-24. Structural data from this study was plotted (Figure 4-7) to correlate observed microstructures with regional tectonic structures discussed in previous studies.
Figure 4-23. Equal area π-diagrams for denoted domains (Figure 4-6) around the ‘core’ of the Strafford Dome. North to top of page. (DI and DII) Poles to bedding plotted with a cylindrical best fit (red) inserted. Although determined separate domains, these most likely can be merged into a single diagram due to the similarities in their plots. The pole plotted to the axial plane (red square) resides within the plotted measured fold axes, suggesting the data is reliable. This most likely represents an F₁ fold generation (i.e. bedding being folded). (DIII) Due to the small domain area and fewer data collected, it is difficult to determine a trend for this (although plots along the cylindrical best fit of DI and DII). (DIV and DV) Similar trend to all previous measurements. Two known fold axes plot near the predicted fold axis (red square), suggesting reliable data.
Figure 4-24. Equal area π-diagrams for denoted domains (Figure 4-6) for the ‘core’ of the Strafford Dome. North to top of page. Circles are poles to planes of bedding parallel cleavage, with cylindrical best fit (red) and predicted fold axis (red square). (DVI and DVII) When plotted together, both of these domains provide a good saddle for the great circle, showing an (expected) N-NNE-trending fold axis. In contrast, (D VIII and DIX) exemplify S-trending fold axes. Plotting measured fold axes (not shown here) for DVII gives a fold axis considerably more NE-trending, although due to the lack of fold axis measurements within the core of the dome, proves unreliable with a cylindrical best fit. Through dividing the core of the dome into these four quadrants, a dome structure emerges (with foliation plunging away from the core).
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Note: oxides are in weight %; trace cations are in ppm.
†% lost on ignition
Figure 4-25. $P$-$T$-$X$ contour of system MnNCKFMASH for the assemblage garnet + biotite + chlorite + plagioclase + muscovite + quartz + H$_2$O (sample TM783; with mass balance invoked on bulk rock chemistries from Table 4-4). Core and rim measurements were made and plotted to show $P$-$T$ path of garnet growth. To prevent clutter, Ti isopleths <6.0 ppm were calculated for activities of ~1.0, and >6.0 ppm for activities of 0.9.
Figure 4-26. *P*-*T*-*X* contour of system MnNCKFMASH for the assemblage garnet + biotite + chlorite + plagioclase + muscovite + quartz + H₂O (sample 09SD08A; with mass balance invoked on bulk rock chemistries from Table 4-4). Core and rim measurements were made and plotted to show *P*-*T* path of garnet growth. To prevent clutter, Ti isopleths <6.0 ppm were calculated for activities of ~1.0, and >6.0 ppm for activities of 0.9.
Figure 4-27. P-T-X contour of system MnNCKFMASH for the assemblage garnet + biotite + chlorite + plagioclase + muscovite + quartz + H₂O (sample TM455; with mass balance invoked on bulk rock chemistries from Table 4-4). Core and rim measurements were made and plotted to show P-T path of garnet growth. To prevent clutter, Ti isopleths <6.0 ppm were calculated for activities of ~1.0, and >6.0 ppm for activities of 0.9.
Figure 4-28. $P$-$T$-$X$ contour of system MnNCKFMASH for the assemblage garnet + biotite + chlorite + plagioclase + muscovite + quartz + H$_2$O (sample 10SD03B2; with mass balance invoked on bulk rock chemistries of TM783 from Table 4-4). Core and rim measurements were made and plotted to show $P$-$T$ path of garnet growth. To prevent clutter, Ti isopleths <6.0 ppm were calculated for activities of ~1.0, and >6.0 ppm for activities of 0.9.
Figure 4-29. $P$-$T$-$X$ contour of system MnNCKFMASH for the assemblage garnet + biotite + chlorite + plagioclase + muscovite + quartz + H$_2$O (sample 10SD03D; with mass balance invoked on bulk rock chemistries of TM783 from Table 4-4). Core and rim measurements were made and plotted to show $P$-$T$ path of garnet growth. To prevent clutter, Ti isopleths <6.0 ppm were calculated for activities of ~1.0, and >6.0 ppm for activities of 0.9.
References


Chapter V

Discussion

1. Thesis Summary

1.1 Strafford Dome Samples

1.1.1 TitaniQ of the Strafford Dome: Findings and implications

Samples TM783, 10SD03B2 and 10SD03D are from proximal localities (within 300 m of each other), all with garnet growth recording temperatures consistently around 565 °C. Pressures are much more variable (~6.5–8.5 kbar), which could reflect pressure increase during garnet growth. Plotting core and rim compositions as contours of garnet species mole fractions on a P-T-X diagram results in $X_{\text{Alm}}$ and $X_{\text{Grs}}$ that intersect at expected P-T conditions, but $X_{\text{Sp}}$ is typically anomalous and occasionally doesn’t intersect these contours at all (Figures 4-25, 4-26, 4-28 and 4-29). This could be attributed to post-growth modification of garnet (due to the already low [Mn], minor modification may result in significant errors). In addition, due to the sensitivity of the P-T-X contour diagrams to the input bulk-rock composition, the size of the garnet porphyroblasts present and the small sample size used for XRF analysis, a truly representative aliquot of the bulk rocks composition of the rocks analyzed may not be achieved...
(which could affect plotted contours). If inclusions within the porphyroblasts were not recrystallizing syn-kinematically (e.g. TM783), then the included quartz rims record conditions typical for the end of D1 deformation. However, if quartz was recrystallizing during garnet growth, increased [Ti] in quartz from garnet core to rim are observed. Rims on quartz grains in the matrix of the majority of these samples yield [Ti] that correlates well with constraints for P-T conditions at the end of D2, suggesting that the majority of matrix quartz was partially recrystallized during these elevated pressures associated with the end of nappe emplacement in the dome (Menard, 1991; Menard and Spear, 1994). In the case of 10SD03D, where garnet growth was post-tectonic with respect to D1, inclusion rims record the elevated [Ti] associated with the end of D2. The matrix material in this sample has a decreased [Ti] relative to the inclusions’ rims, which is caused by recrystallization at higher pressures (unlikely) or during retrograde metamorphism (more probable).

CL imaging of inclusions in garnet often display thin, bright rims on the quartz (typically <5 µm), which is attributed to the diffusion Ti from the garnet (due to the higher [Ti] typically present in garnet relative to quartz). In metamorphic tectonites, dynamic recrystallization of quartz is common with the quartz chemically re-equilibrating Ti during deformation (Kohn and Northrup, 2009). In sample TM455, where subgrain rotation recrystallization is present in a deformed quartz vein, subgrains have lower [Ti] than the relict ribbon quartz grain, suggesting pressure increase or temperature decrease during recrystallization (similar to that observed by Kohn and Northrup, 2009). The preservation of dark quartz cores, as seen in CL, with low [Ti] raises an interesting point in this study that most quartz grains did not fully re-equilibrate with respect to Ti despite deformation. Rather, re-equilibrated rims were observed (in the matrix
and in inclusions) and quartz typically displayed polygonized rims due to static recrystallization. This is most likely due to periods of constant, elevated temperatures following pressure increases associated with D₁ and D₂. One aspect that may influence this result is that in the Strafford Dome rocks analyzed, quartz is not typically the interconnected “weak” phase; mica is. Deformation in these rocks was likely concentrated in the mica rich domains, and isolated quartz grains were effectively undeformed. Lack of interconnectivity between quartz grains would inhibit re-equilibration via dynamic recrystallization (e.g. grain boundary migration) at the recorded temperatures.

Samples that are located east of the dome (towards the Monroe Fault) contain significantly lower [Ti] that reflects the lower temperatures experienced by these rocks (e.g. TM623). Sample 09SD08A preserves higher [Ti] in matrix quartz (attributed to its proximity to the core of the dome). Inclusions in this sample are from the S₁ schistosity, which record peak D₁ conditions at 7 kbar and ~480 °C. Increased P-T results from nappe emplacement. A plot consisting of a summary P-T path for the deformation of rocks in the Strafford Dome (Menard and Spear, 1994), [Ti] isopleths and P-T paths of garnet growth of samples from this study can be found in Figure 5-1. For nearly all samples in the dome, a similar core [Ti] for quartz is recorded (typically 2.5–3.5 ppm). The consistency of this value for samples throughout the dome suggests early prograde (possibly during M₁, where conditions were constant and homogeneous throughout the dome; Menard and Spear, 1994) or relic protolith conditions. Since the protolith is mud with interbedded sandy units that eroded from igneous and metamorphic rocks, variable [Ti] would be expected and makes preservation of these conditions unlikely.
Comparing Ti concentrations from this study to summary $P-T$ paths of previous studies suggest: inclusions have rims recrystallized during the end of D$_1$ deformation, matrix grains have rims re-equilibrated at peak D$_2$, and the dark cores must be from early prograde or relics of the protolith. Locally, other phases of quartz (re)crystallization are documented, such as the matrix quartz from sample 09SD08A preserving darker rims (as seen in CL) with lower [Ti] inferred to be the product of quartz-producing reactions during retrograde metamorphism.

1.1.2 Constraining TiO$_2$ activity during quartz (re)crystallization and the importance of KFMASHTO-system pseudosections in Ti-phase reactions

Calculating $a_{TiO_2}$ must be done carefully and within microstructural context in the samples. It is erroneous to assume that the activity of Ti in the sample is constant for the system. For example, if rutile is present in the matrix, was it also present during quartz recrystallization? In the Strafford Dome samples, rutile is largely absent, but is observed as inclusions in garnet. Ilmenite is present as inclusions and in the matrix. In some samples (e.g. 10SD03B2), ilmenite is abundant as inclusions in garnet porphyroblasts, but is largely absent from the matrix (suggesting an ilmenite-out reaction). The ability to describe what the Ti-essential stoichiometric component is during quartz recrystallization is important to constrain this activity. White et al. (2000) investigated the effect of TiO$_2$ and Fe$_2$O$_3$ on metapelitic assemblages, with a representative pseudosection of the system KFMASHTO produced (Figure 5-2). This pseudosection can be useful in interpreting the potential reactions that may occur in the system effecting Ti-phases. As previously mentioned, caution must be taken in interpreting the $P-T$ conditions of these reactions due to the sensitivity of these diagrams to bulk-rock
chemistries. For the Strafford Dome, rutile may have been present during D\textsubscript{1} deformation, followed by a rutile-out, ilmenite-in reaction after this event (with increased temperatures). The abundance of ilmenite in some porphyroblasts may be evidence of the amount of Ti (and Fe) in the system. The absence of ilmenite in the matrix may be attributed to an ilmenite-out reaction. No Ti-essential phase is present in the matrix in significant concentrations, which is probably the result of biotite formation during retrograde metamorphism.

1.2 The Application of TitaniQ Thermobarometer to \textit{P-T-t-D} Studies of Metamorphic Tectonites

The primary purpose of this study was to test the validity and application of the TitaniQ thermobarometer in \textit{P-T-t-D} history predictions for metamorphic tectonites. This study has revealed several complications that may arise, but also significant benefits to using the TitaniQ thermobarometer.

The first (and possibly most important) complication to using the TitaniQ thermobarometer is the need to independently constrain temperature or pressure during quartz (re)crystallization. To do so, the relative timing of (re)crystallization/re-equilibration associated with other thermobarometers must be coeval with that of quartz. This determination can be challenging, but is facilitated by detailed microstructural analysis to determine the timing of recrystallization relative to deformation (useful with the presence of garnet, as this study has shown). In cases where other trace element thermobarometers are not available (e.g. Zr-in-rutile), other methods may be used which may inherit their own set of complications. If
constraining pressure or temperature cannot be achieved, it is recommended to plot [Ti] isopleths recorded for quartz with different microstructural contexts against predicted P-T paths (e.g. determined by garnet growth). Interpretation of these concentrations becomes more practical if this is done. In the samples analyzed, the absence of rutile in the sample was common and the ability to determine other trace element thermobarometers that recrystallized at the same time as quartz was difficult. To account for this, the [Ti] isopleths were compared to the known P-T history of the dome, as mentioned above.

Another problem that plagues the proper calculation of pressure and temperature from this thermobarometer is the high uncertainties associated with the thermodynamic components (e.g. ΔH and ΔS) that attributes to the majority of P-T uncertainty when calculating propagations of error (Appendix A). Until improved thermodynamic components are established with reduced uncertainties, it is recommended to calculate for ΔP and ΔT (e.g. between core and rim [Ti] measurements in quartz), for this causes many sources of uncertainty to cancel and reduces the associated error greatly compared to measuring absolute P and T (Spear, 1993). Due to the exceptionally low uncertainty of ΔH for the Zr-in-rutile thermobarometer (relative to the ΔH for Ti-in-quartz), when used simultaneously, temperature uncertainties are greatly reduced (<10 °C possible).

Significant benefits arise from the application of the TitaniQ thermobarometer on metamorphic samples. The ability to identify quartz in numerous microstructural settings for individual samples, integrated with the fact that quartz is nearly ubiquitous in continental rocks, makes for a thermobarometer that is applicable in many samples under many conditions across the world. In addition, the ability to determine not only P-T conditions, but also the
interpretation of quartz recrystallization relative to deformation events gives new insight into P-T-t-D history predictions that were previously difficult to achieve. As this study has shown, it is possible to observe core [Ti] in quartz grains that may reflect protolith conditions or early, low-grade equilibrium; great insight that would otherwise be difficult to predict/confirm. Within a single garnet porphyroblast (sample Tm783), three generations of quartz recrystallization are observed and provides further P-T-D points in the rocks’ history that otherwise would be difficult to achieve.

2. Future Work

Due to the limited scope of this study and time constraints associated, there are aspects of TitaniQ thermobarometry that are still unanswered and are recommended for future studies. Many of the garnet porphyroblasts observed contain micro-fractures that sometimes extend from inclusions to the matrix. A question that arose during this study is, do these fractures allow a pathway for Ti within the matrix that will result in post-inclusion re-equilibration? The ability to answer this question is important for in-depth analysis of the inclusions in garnet. Planar defects in quartz were also frequently observed in CL as bright, linear bands present in grains. This leads to the question: what is the impact of defects and micro-fractures on Ti re-distribution in quartz?

The possibility of garnet modification coeval with exhumation has been discussed for these samples and determined to be minimal (with the extent of modification limited to the rim, typically <30 µm). In systems with more extensive modification, what is the impact on quartz
(more specifically [Ti] re-equilibration) during this modification? Lastly, a few [Ti] measurements on quartz veins were measured, and although basic interpretations about vein formation relative to deformation can be made, the confidence in interpreting the [Ti] measurements is low. Further studies on this should focus on the ability to constrain Ti activities for these veins and the ability to accurately calculate P or T if no rutile is present in the vein. Also, if quartz in the vein is recrystallized, will vein thickness (or depth, d) play a role in the degree of Ti re-equilibration?

Although further work must be conducted to better understand the TitaniQ thermobarometer, significant benefits for using this method have been observed during the course of this study. If care is taken when using the method and the procedure outlined in Chapter III is taken into consideration during analysis, the TitaniQ thermobarometer can be an important tool in tectonic studies and P-T-t-D path calculations for metamorphic tectonites.
Figure 5-1. $P$-$T$-$D$ plot including summary $P$-$T$ plot (purple, dashed line) from Menard and Spear (1994), select Ti isopleths (brown and blue dotted lines) and $P$-$T$ paths for various garnets throughout the Strafford Dome (black lines; this study). Solid blue line is $P$-$T$ conditions experienced at the end of $D_1$, with the red box representing conditions experienced at the end of $D_2$ (Menard and Spear, 1994).
Figure 5-2. Pseudosection for the system KFMASHTO (White et al., 2000). Such pseudosections can be used to describe the reactions that take place with Ti-phases necessary for estimating Ti activities during quartz recrystallization. In this case, the rutile-out, ilmenite-in reaction is highlighted (blue). From White et al. (2000).
References


Comprehensive Bibliography


granulite genesis. Contributions to Mineralogy and Petrology, 139(2), 180-197.


American Journal of Science, 290, 360-395.


Johnson, S. E., 1993b. Testing models for the development of spiral-shaped inclusion trails in garnet porphyroblasts: To rotate or not to rotate, that is the question. Journal of Metamorphic Geology, 11, 635-659.


Appendix A

When using the Ti-in-quartz thermobarometer, propagation of error of all inputs must be calculated for to accurately represent the uncertainties. In addition, a MATLAB program script, Program ThermobarQ, has been written to calculate P and T using the TitaniQ thermobarometer (with propagated errors), while allowing the option to combine this with various other thermobarometers (e.g. Zr-in-rutile). The script was written to provide the most user-friendly interface possible and allow the flexibility in using these calculations. Calculation outputs are displayed and the P-T plots produced can be saved directly from the program in a variety of formats (e.g. jpeg, bitmap, tiff, MATLAB image, adobe illustrator, etc.). The image can also be copied directly from MATLAB and pasted in CorelDRAW with all conditions preserved and editable (Figure A-1). The .m-file and user manual can be downloaded at https://sites.google.com/site/ashleygeology/thermobarq. Included are the program script, which can be copied into a blank script and saved, and the user manual.
1. P-T Calculation and Propagation of Error

When calculating pressure (P) with the Ti-in-quartz (“TitaniQ”) thermobarometer, error estimates must account for error associated with five variables: change in enthalpy (ΔH), change in entropy (ΔS), temperature (T), the mole fraction of TiO₂ in quartz (X_{TIO₂}^{qtz}), and change in volume (ΔV). The equation is (calculated from least-squares method from experimental measurements):

\[ P = \frac{-\Delta H + \Delta S T - R \left[ \ln (X_{TIO₂}^{qtz}) - \ln (a_{TIO₂}^{qtz}) \right]}{\Delta V} \]  

where R is the ideal gas constant (R = 8.31447 J mol⁻¹ K⁻¹). The input \( \ln (a_{TIO₂}^{qtz}) \) equals zero when the activity is fixed at 1 (e.g. rutile present), and is assumed to be true for the following calculations. This allows for the equations to be simplified and was a preferred criterion for sample selection during this project. The correct way of calculating for this error is through partial derivatives and the adding in quadrature, as shown here:

\[ \sigma f(x₁, x₂, x₃, ...) = \sqrt{\left( \frac{\partial f}{\partial x₁} \sigma x₁ \right)^2 + \left( \frac{\partial f}{\partial x₂} \sigma x₂ \right)^2 + \left( \frac{\partial f}{\partial x₃} \sigma x₃ \right)^2} + ... \]  

where \( \frac{\partial f}{\partial x₁} \) is the partial derivative of \( f \) with respect to \( x₁ \). The partial derivatives of all sources of input uncertainties are as follow. For simplicity purposes, the partial derivative calculations shown for ΔH (eq. A-3) are not shown for ΔS, T, ΔV or \( X_{TIO₂}^{qtz} \) (eqs. A-4 through A-7). The partial derivatives are:

\[ P_{\Delta H} = \frac{\partial P}{\partial \Delta H} = \frac{\partial}{\partial \Delta H} \left[ -\Delta H + \Delta S T - R \ln (X_{TIO₂}^{qtz}) \right] \frac{\Delta V}{\Delta V} \sigma \Delta H \]
\[
\sigma P (\Delta H, \Delta S, T, \Delta V, X_{\text{TiO}_2}^{\text{qtz}}) = \sqrt{\left(\frac{\partial P}{\partial \Delta H} \sigma \Delta H\right)^2 + \left(\frac{\partial P}{\partial \Delta S} \sigma \Delta S\right)^2 + \left(\frac{\partial P}{\partial T} \sigma T\right)^2 + \ldots}
\]

\[
\sigma P = \sqrt{\left(-\frac{1}{\Delta V} \sigma \Delta H\right)^2 + \left(\frac{T}{\Delta V} \sigma \Delta S\right)^2 + \left(\frac{\Delta S - R \ln \left(X_{\text{TiO}_2}^{\text{qtz}}\right)}{\Delta V} \sigma T\right)^2 + \ldots}
\]

Adding the quadrature gives:

\[
\frac{\partial P}{\partial \Delta V} \sigma \Delta V = \frac{\Delta H - \Delta ST - RT \ln \left(X_{\text{TiO}_2}^{\text{qtz}}\right)}{(\Delta V)^2} \sigma \Delta V
\]
Setting the thermodynamic equation equal to $T$ rearranges the equation to:

$$T = \frac{PDV + \Delta H}{\Delta S - R \ln \left( \frac{X_{TiO_2}^{qtz}}{X_{TiO_2}} \right)}$$  \hspace{1cm} (A-11)$$

The propagation of error for calculating $T$ is:

$$\sigma T = \sqrt{\left[ \frac{P \sigma DV}{\Delta S - R \ln \left( \frac{X_{TiO_2}^{qtz}}{X_{TiO_2}} \right)} \right]^2 + \left[ \frac{\Delta V \sigma PDV}{\Delta S - R \ln \left( \frac{X_{TiO_2}^{qtz}}{X_{TiO_2}} \right)} \right]^2 + \left[ \frac{\sigma DH}{\Delta S - R \ln \left( \frac{X_{TiO_2}^{qtz}}{X_{TiO_2}} \right)} \right]^2 + \ldots}$$

$$\sqrt{\ldots + \left[ \frac{P \Delta V + \Delta H}{\Delta S^2 - 2 \ln \left( \frac{X_{TiO_2}^{qtz}}{X_{TiO_2}} \right) R \Delta S + \ln^2 \left( \frac{X_{TiO_2}^{qtz}}{X_{TiO_2}} \right) R^2} \right]^2 (\sigma \Delta S)^2 + \ldots}$$

$$\sqrt{\ldots + \left[ \frac{P R \Delta V + \Delta HR}{X_{TiO_2}^{qtz} \Delta S^2 - 2 X_{TiO_2}^{qtz} R \Delta S + X_{TiO_2}^{qtz} \ln^2 \left( \frac{X_{TiO_2}^{qtz}}{X_{TiO_2}} \right) R^2} \right]^2 \left( \sigma X_{TiO_2}^{qtz} \right)^2 \ldots}$$  \hspace{1cm} (A-12)$$

The equations to convert $Ti$ (ppm) to mole fraction $\text{TiO}_2$ in quartz ($X_{TiO_2}^{qtz}$), $Zr$ (ppm) to mole fraction $\text{ZrO}_2$ in rutile ($X_{ZrO_2}^{rutile}$), and $Zr$ (ppm) to mole fraction $\text{ZrO}_2$ in titanite ($X_{ZrO_2}^{sphene}$) are

(from Thomas et al., 2010):

$$X_{TiO_2}^{qtz} = \frac{\frac{Ti \text{ (ppm)}}{1E4 \times 0.599 \times 79.87}}{\frac{Ti \text{ (ppm)}}{1E4 \times 0.599 \times 79.87} + \left[ \left( 100 - \frac{Ti \text{ (ppm)}}{1E4 \times 0.599 \times 79.87} \right) \times \frac{1}{60.09} \right]}$$  \hspace{1cm} (A-13)$$
Propagation of error for variants of these equations (e.g. calculating for a system with $a_{{\text{qtz}}}^{\text{qtz}} < 1$; eq. A-1 and A-11) can be done by following the steps provided. Likewise, this can be used with other thermobarometers, such as Zr-in-rutile and Zr-in-sphene, by simply changing the thermodynamic inputs (i.e. $\Delta H$, $\Delta S$ and $\Delta V$; Table A-1) to ones relative for that system. There are many online derivative calculators available that may serve useful as a self-check in the accuracy of calculations.

It is important to note that the work shown above is for calculating the total precision of absolute pressure (or temperature), and the uncertainties associated with calculating pressure (or temperature) differences ($\Delta P$ or $\Delta T$) are greatly reduced since many of the sources of uncertainty cancel when taking the difference (Spear, 1993).

\[
X_{\text{rutile}}^{\text{ZrO}_2} = \frac{Zr \text{ (ppm)}}{1E4 \times 0.74 \times 123.22 + \left(100 - \frac{Zr \text{ (ppm)}}{1E4 \times 0.74 \times 123.22}\right) \times 1 \frac{1}{79.87}}
\]

\[
X_{\text{sphene}}^{\text{ZrO}_2} = \frac{Zr \text{ (ppm)}}{1E4 \times 0.74 \times 123.22 + \left(100 - \frac{Zr \text{ (ppm)}}{1E4 \times 0.74 \times 123.22}\right) \times 1 \frac{1}{196.03}}
\]
2. Program ThermobarQ MATLAB Script

%%
%%%ThermobarQ - Ti-in-Quartz Thermobarometer Calculator
%%%Script written by Kyle T. Ashley, MSc Candidate
%%%University of Vermont, Department of Geology
%%%Updated March, 2011; V. 1.0.3 - Copyright 2011

%%%Note: calculations for P-T with the TitaniQ thermobarometer is made possible
%%%with: well constrained P or T; use of another thermobarometer.
%%%Zr-in-sphene thermobarometer (e.g. Hayden et al., 2008), Ti-in-zircon and
%%%Zr-in-rutile thermometers (e.g. Ferry and Watson, 2007) are used as
%%%alternate isopleths to constrain P-T conditions.

clear;
c1c;
disp('Welcome to ThermobarQ V. 1.0.3!')
disp('Calculating P-T with Ti-in-Quartz Thermobarometer')
disp('Program script written by Kyle T. Ashley, MSc')
disp('Updated March 15, 2011 - Copyright 2011')
disp('Press [Enter] to continue...')
pause;
disp(' ')

******************************************************************************
%% 1. Known Constants
******************************************************************************
R = 8.314472; %Gas constant, J/mol*K
dHq = 60952; %change in enthalpy for Ti-in-quartz

******************************************************************************
%% Table of Contents
******************************************************************************

%%% Organization of this file:
%%% 
%%% 1. Constants
%%% 2. Calculating P with known T
%%% 3. Calculating T with known P
%%% 4. P-T Calculation with Ti-in-Quartz and Zr-in-rutile
%%% 5. P-T Calculation with Ti-in-Quartz and Zr-in-titanite
%%% 6. P-T Calculation with Ti-in-Quartz and Ti-in-zircon
%%% 7. Other

******************************************************************************
sdHq = 3177; %Sigma dHq (error)
dSq = 1.52; %change in entropy for Ti-in-quartz
sdSq = 0.39; %Sigma dSq (error)
dVq = 1741; %change in volume for Ti-in-quartz
dVr = 476; %change in volume for Zr-in-rutile
dVs = 1538; %change in volume for Zr-in-sphene

dHr = 85500; %change in enthalpy for Zr-in-rutile
dHr = 5; %Sigma dHr (error)
dSr = 29.1; %change in entropy for Zr-in-rutile
dSr = 3; %Sigma dSr (error)
dVr = 476; %change in volume for Zr-in-rutile
dVr = 39; %Sigma dVr (error)
dHs = 145943; %change in enthalpy for Zr-in-sphene
dHs = 5834; %Sigma dHs (error)
dSs = 88.9; %change in entropy for Zr-in-sphene
dSs = 6; %Sigma dSs (error)
dVs = 128; %Sigma dVs (error)

disp('Note that using the Ti-in-quartz ("TitaniQ") thermobarometer')
disp('requires a constraint of either pressure or temperature.')
disp('Simultaneous use with another thermobarometer can also be used')
disp('for constraining P-T.')
disp('')
disp('Press [Enter] to continue...')

pause;

method = menu('How will you be calculating P-T?', 'Calculating P with known T', 'Calculating T with known P', 'Constrain P-T with use of Zr-in-rutile thermobarometer', 'Constrain P-T with use of Zr-in-titanite thermobarometer', 'Constrain P-T with use of Ti-in-zircon thermometer');
disp('')

2. Calculating P with known T

if method == 1
    T = input('Temperature (deg. C): ') + 273.15;
    Tc = T - 273.15; %Temperature in deg. C
    sT = input('Temperature error (deg. C): ');
    disp('')
    activity = menu('What is the activity of TiO2 in quartz?', 'Fixed at 1 (rutile present)', 'Estimate activity from minerals present', 'Enter known activity');
    if activity == 1
        aTiO2 = 1;
    elseif activity == 2
        aQT = menu('Select mineral phase present:', 'Ilmenite', 'Titanite', 'Other');
        if aQT == 1
            Y = input('Please input % ilmenite (as decimal) of ilmenite-hematite solid solution: ');
        end
    end
end
\[ X = \text{input('Please input % ulvospinel (as decimal) of ulvospinel-magnetite solid solution: ')}; \]
\[ a\text{TiO}_2 = ((\exp(-14176/(T*8.31447))*Y^2)/X); \]
\[ \text{elseif } aQT == 2 \]
\[ a\text{TiO}_2 = 0.5; \]
\[ \text{else} \]
\[ a\text{TiO}_2 = \text{input('Please input estimated activity of TiO}_2 \text{ in quartz: ')}; \]
\[ \text{end} \]
\[ \text{elseif} \]
\[ a\text{TiO}_2 = 0.5; \]
\[ \text{else} \]
\[ a\text{TiO}_2 = \text{input('Please input estimated activity of TiO}_2 \text{ in quartz: ')}; \]
\[ \text{end} \]
\[ T_{\text{minus}_\text{error}} = T - sT; \text{ %estimated temperature minus error} \]
\[ T_{C\text{minus}_\text{error}} = Tc - sT; \]
\[ T_{\text{plus}_\text{error}} = T + sT; \text{ %estimated temperature plus error} \]
\[ T_{C\text{plus}_\text{error}} = Tc + sT; \]
\[ T_{\text{min}} = T - 100; \text{ %constraints for isopleths on plot} \]
\[ T_{\text{min}} = Tc - 100; \]
\[ T_{\text{max}} = T + 100; \text{ %constraints for isopleths on plot} \]
\[ T_{\text{max}} = Tc + 100; \]
\[ \%	ext{Ti measurement input (ppm) and conversion to mole fraction} \]
\[ \text{Ti} = \text{input('Ti concentration in quartz (ppm): ')}; \]
\[ s\text{Ti} = \text{input('Ti concentration error (ppm): ')}; \]
\[ z = \text{Ti}/(10000*0.599*79.87); \%	ext{converting from Ti (ppm) to mole fraction of TiO}_2 \text{ in quartz} \]
\[ X = z/(z+((100-z)/60.09)); \]
\[ \%	ext{converting from Ti (ppm) error to mole fraction of TiO}_2 \text{ in quartz} \]
\[ sX = sz/(sz+((100-sz)/60.09)); \]
\[ \%	ext{Calculating pressure from temperature estimates} \]
\[ P = (-(dHq+(dSq*T)-(R*T*(log(X)-log(a\text{TiO}_2)))))/(dVq); \]
\[ \%	ext{Calculating propagation of error for the above equation} \]
\[ a = (sdHq/dVq)^2; \]
\[ b = (T*sdSq/dVq)^2; \]
\[ c = (((dSq -(R*(log(X)-log(a\text{TiO}_2))))/(dVq))^2)*sT^2); \]
\[ d = (((R*T*sX)/(X*dVq))^2; \]
\[ e = (((R*T*(log(X)-log(a)))-(dSq*T)+(dHq)/(dVq^2))^2)*(sdVq^2); \]
\[ sP = (a+b+c+d+e)^{(1/2)}; \]
\[ P_{\text{minus}_\text{error}} = P-sP; \]
\[ P_{\text{plus}_\text{error}} = P+sP; \]
\[ \%	ext{Output conditions} \]
\[ \text{disp(' ')} \]
\[ \text{disp('P-T conditions')} \]
\[ \text{disp(' ')} \]
\[ \text{fprintf(''[Ti] (ppm): %.3g ')}; \]
\[ \text{Ti} \]
fprintf('Activity of TiO2 in quartz: %.3g', aTiO2)
disp('  ')
fprintf('Temperature (deg. C): %.5g ', Tc)
disp('  ')
fprintf('Pressure (kbar): %.3g ', P)
disp('  ')

T_pmin = P - 5; % range of temp-estimated line from calculated P-T
T_pmax = P + 5; % range of temp-estimated line from calculated P-T

P_tmin = (-dHq+(dSg*Tmin)-(R*Tmin*(log(X)-log(aTiO2))))/(dVq);
P_tmax = (-dHq+(dSg*Tmax)-(R*Tmax*(log(X)-log(aTiO2))))/(dVq);
P1min = P_tmin - sP;
P1max = P_tmin + sP;
P2min = P_tmax - sP;
P2max = P_tmax + sP;

% Constructing the plot
Tc_plot = [Tc; Tc];
T_p_plot = [T_pmin; T_pmax];
Tc_min_plot = [Tc_minus_error; Tc_minus_error];
Tc_max_plot = [Tc_plus_error; Tc_plus_error];
P_plot = [P_tmin; P_tmax];
P_plot_tc = [Tcmin; Tcmax];
P_min_plot = [P1min; P2min];
P_max_plot = [P1max; P2max];

% Setting up Kyanite-Sillimanite-Andalusite Reference Fields
KAt = [450; 622];
KAp = [3.642; 5.5];
KSt = [622; 800];
KSp = [5.5; 9.81];
AST = [622; 800];
ASp = [5.5; 1.15];

plot(KAt, KAp, 'k-', KSt, KSp, 'k-', AST, ASp, 'k-', Tc_plot,
    T_p_plot, 'b-', Tc_min_plot, T_p_plot, 'r--', Tc_max_plot, T_p_plot,
    'r--', P_plot_tc, P_plot, 'b-', P_plot_tc, P_min_plot, 'r--',
    P_plot_tc, P_max_plot, 'r--')
xlabel('Temperature (deg. C)')
ylabel('Pressure (kbar)')
title('Calculating P with Known T')
elseif method == 2
    P = input('Pressure (kbar): ');
    sP = input('Pressure error (kbar): ');
    disp(''
    activity = menu('What is the activity of TiO2 in quartz?', 'Fixed at 1 (rutile present)', 'Estimate activity from minerals present', 'Enter known activity');
        if activity == 1
            aTiO2 = 1;
        elseif activity == 2
            aQT = menu('Select mineral phase present:', 'Ilmenite', 'Titanite', 'Other');
                if aQT == 1
                    aTiO2 = 1
                elseif aQT == 2
                    aTiO2 = 0.5;
                else
                    aTiO2 = input('Please input estimated activity of TiO2 in quartz: ');
                end
        else
            aTiO2 = input('Please input estimated activity of TiO2 in quartz: ');
        end
    end

    %Ti measurement input (ppm) and conversion to mole fraction
    Ti = input('Ti concentration in quartz (ppm): ');
    sTi = input('Ti concentration error (ppm): ');
    z = Ti/(10000*0.599*79.87); %converting from Ti (ppm) to mole fraction of TiO2 in quartz
    X = z/(z+(100-z)/60.09));
    sz = sTi/(10000*0.599*79.87); %converting from Ti (ppm) error to mole fraction of TiO2 in quartz
    sX = sz/(sz+(100-sz)/60.09));

    P_minus_error = P - sP; %estimated temperature minus error
    P_plus_error = P + sP; %estimated temperature plus error
    Pmin = P - 5; %constraints for isopleths on plot
    Pmax = P + 5; %constraints for isopleths on plot

    %Calculating temperature from pressure estimates
    T = ((P*dVq)+dHq)/(dSq-(R*(log(X)-log(aTiO2)))); %Temperature is in Kelvin
    Tc = T - 273.15; %Temperature in deg. Calculus

    %Calculating propagation of error for the above equation
    a = (((dVq*sP)/(((log(X)-log(aTiO2))*R)-dSq))^2);
\[
b = \frac{(sdVq\times P)}{((\log(X) - \log(aTiO2))\times R - dSq)^2};
\]
\[
c = \frac{(sdHq)}{((\log(X) - \log(aTiO2))\times R - dSq)^2};
\]
\[
d = \frac{((dVq\times P) + dHq)}{((\log(X)^2 - (2\times \log(aTiO2))\times \log(X) + (\log(aTiO2)^2)\times (R^2)) + ((2\times \log(aTiO2) + 1)\times \log(X))\times (R^2) + ((2\times \log(aTiO2) + 1)\times \log(X))\times (R^2) + ((2\times \log(aTiO2) + 1)\times \log(X))\times (R^2))\times (sX^2));
\]
\[
e = \frac{((dVq\times P) + dHq)\times R}{((\log(X)^2 - (2\times \log(aTiO2))\times \log(X) + (\log(aTiO2)^2)\times (R^2)) + ((2\times \log(aTiO2) + 1)\times \log(X))\times (R^2) + ((2\times \log(aTiO2) + 1)\times \log(X))\times (R^2))\times (sX^2));
\]
\[
sT = (a+b+c+d+e)^{1/2};
\]
\[
T_{\text{minus error}} = T - sT;
\]
\[
T_{\text{plus error}} = T + sT;
\]

%Output conditions

disp(' ')
disp('P-T conditions')
disp(' ')
fprintf('[Ti] (ppm): %.3g ', Ti)
fprintf('+/- %.3g', sTi)
disp(' ')
fprintf('Activity of TiO2 in quartz: %.3g', aTiO2)
disp(' ')
fprintf('Temperature (deg. C): %.3g', Tc)
fprintf('+/- %.3g', sT)
disp(' ')
fprintf('Pressure (kbar): %.3g', P)
fprintf('+/- %.3g', sP)
disp(' ')

%Set-up for plotting isopleths

P_tmin = Tc - 100; %range of press-estimated line from calculated P-T
P_tmax = Tc + 100; %range of press-estimated line from calculated P-T

Tc_pmin = (((Pmin*dVq)+dHq)/(dSq-(R*(\log(X) - \log(aTiO2))))) - 273.15;
Tc_pmax = (((Pmax*dVq)+dHq)/(dSq-(R*(\log(X) - \log(aTiO2))))) - 273.15;
T1min = Tc_pmin - sT;
T1max = Tc_pmin + sT;
T2min = Tc_pmax - sT;
T2max = Tc_pmax + sT;

%Constructing the plot

P_plot = [P; P];
P_t_plot = [P_tmin; P_tmax];
P_min_plot = [P_minus_error; P_minus_error];
P_max_plot = [P_plus_error; P_plus_error];
Tc_plot = [Tc_pmin; Tc_pmax];
Tc_plot_p = [Pmin; Pmax];
Tc_min_plot = [T1min; T2min];
Tc_max_plot = [T1max; T2max];
%Setting up Kyanite-Sillimanite-Andalusite Reference Fields
KAt = [450; 622];
KAp = [3.642; 5.5];
KSt = [622; 800];
KSp = [5.5; 9.81];
ASp = [622; 800];
ASp = [5.5; 1.15];

plot(KAt, KAp, 'k-', KSt, KSp, 'k-', ASp, 'k-', P_t_plot, P_plot, 'b-', P_t_plot, P_min_plot, 'r--', P_t_plot, P_max_plot, 'r--', Tc_plot, Tc_plot_p, 'b-', Tc_min_plot, Tc_plot_p, 'r--', Tc_max_plot, Tc_plot_p, 'r--')
xlabel('Temperature (deg. C)')
ylabel('Pressure (kbar)')
title('Calculating T with Known P')

end

break;

Program ThermobarQ

v. 1.0.3 (March 2011) – © 2011

User Manual

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Forward

The purpose of Program ThermobarQ is to make calculations for the Ti-in-quartz ("TitaniQ") thermobarometer, accounting for the propagation of error and constraining activities of Ti in quartz \(a_{\text{TiO}_2}^{\text{qtz}}\), while maintaining a graphical user interface (or GUI) that makes for an easy-to-use program. The program was designed in such a way that by following this short manual, even a person who has never used MATLAB can use ThermobarQ successfully. The MATLAB platform was selected for programming in for several reasons: the wide-spread use of the program in various fields, the experience the author has with the program, as well as the capabilities of the program to make an interactive interface that is absent from other programs (e.g. R). In addition, the program can be easily edited to remain up-to-date (e.g. changes in thermodynamic constants, such as enthalpy, entropy and volumetric changes).

Over time, many changes are expected to be made to the program. Future modifications that are anticipated are: including the use of other thermobarometers to constrain P-T conditions, producing multi-function GUI windows that limit the number of steps in the calculation and limits the use of the Command Window, as well as allowing for numerous spot analyses instantaneously through uploading an Excel file into the program. Feedback is
greatly appreciated and encouraged to allow for the program revisions to be as productive as possible. Appendix A.1 provides additional detail about the calculation of propagation of error and other important calculations that are made with the program; Chapter 2.1.2 discusses the ilmenite-ulvöspinel activity calculations that are made. Good luck in your thermobarometric analyses!

I. Program Download and Saving Directory

If you have stumbled across this manual, then most likely you have found Program ThermobarQ as well. The program is a .m file that must be saved in the MATLAB directory. The file should be saved to the “work” folder, which can be found at:

My Computer  C:  Program Files  MATLAB  work

If saved successfully in the proper location, when MATLAB is opened, ThermobarQ.m should be listed in the Current Directory (see below as to where this directory is located).

II. MATLAB-User Interface

The problem with many programs is the difficulty navigating, and getting use to, the interface. So if numerous programs are used in the research project, this task may become daunting and frustrating. MATLAB provides a straight-forward interface with only a couple of windows that will be used regularly.

Below is a screen shot of MATLAB when opened. The Current Directory is where you should see ThermobarQ.m if the file was saved in the correct location (black arrow). Besides the file name present, this window also gives information about the file including: file type (should be M-file), file size, date the file was last modified and a brief description of the file. There is a “Workspace” tab that can be selected, and contains all of the parameters used in the program, their values and the class (double for most parameters in this program). The Command History list all of the past inputs entered into the Command Window. The Command Window is the input-output user interface that you will spend the most time working in. When the program is started, on-screen commands will be displayed that will navigate work flow and instruct the user what to input. A GUI window will open occasionally during use of this program that allows for a more interactive interface for the user. This will occur when selecting how the P-T calculations will be handled, deciding how to constrain Ti activities, etc. Besides being aesthetically appealing, this interface actually allows for the bypassing of numerous steps and results in simple, time-saving calculations.
III. Using Program ThermobarQ

You now have your file saved in the work folder and you know the basic functions of each window that you will be working with. There are two ways to start Program ThermobarQ: by right-clicking the ThermobarQ.m file shown in the Current Directory window and selecting run, or by typing in the Command Window “run ThermobarQ.” If done so correctly, you should see the following in the Command Window:

```
Welcome to ThermobarQ v. 1.0.3!
Calculating P-T with Ti-in-Quartz Thermobarometer
Program script written by Kyle T. Ashley, MSc
Updated March 15, 2011
Press [Enter] to continue...
```

This is the program’s masterhead. Hitting [Enter] will return the note that to correctly use this thermobarometer, an independent constraint on either pressure or temperature is required; or simultaneous use with another thermobarometer can be used to constrain both P
and T. Hitting [Enter] again will initiate the program. A menu GUI will pop-up allowing for different options in your TitaniQ calculations. Note that although use with other trace-element thermobarometers is currently listed, this is a function that will not be available until a later version of the program is released. If one of these are selected, the program will self terminate and requires being re-opened.

Whether selecting calculating P with known T, or calculating T with known P, the next step requires you to input the known condition and the error associated. After this is entered, a second GUI window opens for constraining Ti activity for the sample. There are three choices to choose from: fix activity at 1 (assuming rutile is present), estimate the activity from the minerals present (including using the ilmenite-ulvöspinel system to constrain this), or by entering a known activity value (there are various published activities typical for different rock types that can be entered in absence of any known value; e.g. Ghent and Stout, 1984).

The last step in the TitaniQ calculations is entering the [Ti] (in ppm) with associated error. Once [Enter] is hit, two things will happen: a figure window will open displaying P-T space with calculated uncertainties, and all calculation parameters and outputs will be displayed in the Command Window in the main interface. Below is a typical sample run, with accompanying graph:

```
<StudentVersion> Command Window
Welcome to ThermobarQ V. 1.0.0!
Calculating P-T with Ti-in-quartz Thermobarometer
Program script written by Kyle T. Ashley, MS
Updated March 15, 2011

Press [Enter] to continue...

Note that using the Ti-in-quartz ("TitaniQ") thermobarometer requires a constraint of either pressure or temperature. Simultaneous use with another thermobarometer can also be used for constraining P-T.

Press [Enter] to continue...

Temperature (deg. C): 550
Temperature error [deg. C]: 25

[Ti] concentration in quartz [ppm]: 5.9
[Ti] concentration error [ppm]: .15

P-T conditions

[Ti] (ppm): 8.0 +/- 0.15
Activity of TiO2 in quartz: 1
Temperature (deg. C): 550 +/- 25
Pressure (kbar): 10.5 +/- 2.35
EPR: >
```
In the plot above, the solid blue lines correspond to the calculated (or input) pressure and temperatures. The dashed red lines correspond to the propagated error calculated from the uncertainties of the parameters. The solid black lines correspond to the kyanite-sillimanite-andalusite stability fields, and serves as a reference for the plot.

This plot can be saved as various image file types (JPEG, Bitmap, TIFF, etc.) by selecting File → Save As. If figure editing is preferred (and is recommended), the file can be saved as an Adobe Illustrator file in the same manner, or Edit → Copy Figure can be selected, allowing for the user to paste the figure (with all parameters preserved and conditions editable) in another image editing/drafting program (such as CorelDRAW). A recommended formatting for the figure may be similar to what is displayed in Figure A-1.
Figure A-1. Plot calculating pressure with known temperature using TitaniQ thermobarometry in Program ThermobarQ. Propagation of error was calculated and is represented by the red dashed lines.

Table A-1. Least square fit parameters for thermobarometric calculations

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Ti-in-quartz</th>
<th>Zr-in-rutile</th>
<th>Zr-in-sphene</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a$</td>
<td>60,952 ± 3,177</td>
<td>85,500 ± 5</td>
<td>145,943 ± 5,834</td>
</tr>
<tr>
<td>$b$</td>
<td>1.52 ± 0.39</td>
<td>29.1 ± 3</td>
<td>88.9 ± 6</td>
</tr>
<tr>
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Ti-in-quartz (Wark and Watson, 2006), Zr-in-rutile (Tomkins et al., 2007), and Zr-in-sphene (Hayden et al., 2007) data was used with the parameters from the least square fit calculated by Thomas et al. (2010).

n.a. = not applicable; n.d. = not determined.

$W^*$ = interaction parameter (kJ/mol) to account for the higher [Zr] in rutile (Tomkins et al., 2007; Thomas et al., 2010).
References


Appendix B

Target quartz grains for SIMS analysis and results. Plates begin with a photomicrograph image of the sample, with CL locations illustrated. CL images without spot analysis (green boxes) are also included to provide a more comprehensive Ti distribution analysis for the sample. Plates immediately following this contain CL images (blue filtered) with spot locations noted (including associated [Ti], from Appendix B; red boxes). Included in each spot analysis marked is the [Ti] (in ppm), followed by the analysis number in parentheses (from Appendix B).
Appendix B
Sample: TM783
Plate 1
CL Location Map

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187
Notes: (a) concentric bright zoning is an artifact of CL mirror off-alignment that causes brighter CL in the middle and decreasing outwards. (b) Mirror off-alignment causing false zoning, brighter to the left of the image, darkening to the right. This is the similar case for (c) and (d).
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**Note:** Photomicrographs depicting CL image locations for 09SD08A were taken after the sample was microdrilled and the 1” round was prepared due to sample limitations (e.g. being able to definitively determine location in coarse-grained quartz vein). The epoxy can give non-isotropic grains a false birefringence in cross-polarized, transmitted light. ps* = pressure shadow.
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Sample: 09SD08A
Plate 6

CL Location Map

**Matrix**

**Vein**

- **e**
- **f**
- **g**
Notes: (d) Dashed line is outline of electron beam damage from BSE imaging.
Notes: (e) and (g) Dashed line is outline of electron beam damage from BSE imaging.
Sample: TM455

Appendix B

Plate 9

CL Location Map

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Note: (c) CL image is rotated ~180° relative to photomicrograph.
Sample: TM455

Appendix B
Plate 10

CL Images

2.8 (63)

4.7 (64)

5.1 (65)

4.9 (66)

3.7 (61)

4.7 (59)

3.5 (62)

4.8 (60)
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**Note:** Photomicrograph depicting CL image locations for TM623 were taken after the sample was microdrilled and the 1” round was prepared due to sample limitations (e.g. being able to definitively determine location of crenulations in matrix). The epoxy can give non-isotropic grains a false birefringence in cross-polarized, transmitted light.
Sample: TM623
Plate 12
CL Images

Appendix B

5.6 (27)
2.6 (29)
3.4 (28)
2.2 (30)
2.4 (31)
5.6 (27)
Appendix B
Sample: 10SD03B2
Plate 13
CL Location Map

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Sample: 10SD03B2
Plate 14
CL Images

**Appendix B**

Plate 14

CL Images

5.9 (96)
5.8 (97)
8.2 (95)
9.7 (94)

7.0 (93)
7.8 (92)
4.8 (91)
5.2 (90)

4.7 (86)
5.2 (87)
7.4 (89)
7.7 (88)
### Sample: 10SD03D

#### Appendix B

Plate 16

**CL Location Map**

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Key

![Image of a CL Location Map with labeled locations and a scale bar of 2000 μm]
Sample: 10SD03D
Plate 17
CL Images

Note: Due to the CL mirror being off-centered, there is a zoning in CL images from this sample, with increasing brightness to the left of the images.
Appendix C

Data repository of spot analyses conducted on the secondary ion mass spectrometer (SIMS) at Woods Hole Oceanographic Institute, MA. Output concentrations are in isotopic ratios, which is corrected for and calibrated against four known standards (Qtip-38, -7, -14 and -39). Ti (ppm) is calculated for each spot analysis, with the standard deviation calculated for over the 10 cycles. A summary table of all spot analyses is included at the beginning of the repository.
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Standard Dev. (ppm): N/A

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Standard Dev. (ppm): N/A
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Standard Dev. (ppm): N/A

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Standard Dev. (ppm): 0.23
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Standard Dev. (ppm): N/A

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Standard Dev. (ppm): 0.23
### Standard 7: Qtip39 – 1

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Standard Dev. (ppm): N/A

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Standard Dev. (ppm): N/A
### Spot 1: Sample TM783 – Area D

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Standard Dev. (ppm): 0.24

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Standard Dev. (ppm): 0.10
## Spot 3: Sample TM783 – Area D

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## Spot 4: Sample TM783 – Area D

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**Standard Dev. (ppm): 0.10**

### Spot 6: Sample TM783 – Area C

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**Standard Dev. (ppm): 0.19**
# Spot 7: Sample TM783 – Area C

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Standard Dev. (ppm): 0.12

# Spot 8: Sample TM783 – Area C

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Standard Dev. (ppm): 0.12
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Standard Dev. (ppm): 0.14

### Spot 10: Sample TM783 – Area C

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Standard Dev. (ppm): 0.26
**Spot 11: Sample TM783 – Area A**

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*Standard Dev. (ppm): 0.20*

**Spot 12: Sample TM783 – Area A**

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*Standard Dev. (ppm): 0.19*
### Spot 13: Sample TM783 – Area A

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Standard Dev. (ppm): 0.30

### Spot 14: Sample TM783 – Area A

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Standard Dev. (ppm): 0.35
### Spot 15: Sample TM783 – Area A

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Standard Dev. (ppm): 0.18

### Spot 16: Sample TM783 – Area A

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Standard Dev. (ppm): 0.17
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Standard Dev. (ppm): 0.12

### Spot 18: Sample TM783 – Area B

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Standard Dev. (ppm): 0.16
## Spot 19: Sample TM783 – Area B

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Standard Dev. (ppm): 0.27

## Spot 20: Sample TM783 – Area B

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Standard Dev. (ppm): 0.14
### Spot 21: Sample TM783 – Area B

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**Standard Dev. (ppm):** 0.18

### Spot 22: Sample TM783 – Area B

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**Standard Dev. (ppm):** 0.13
### Spot 23: Sample TM783 – Area B

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<th>time (s)</th>
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<th>time (s)</th>
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<th>$^{48}$Ti/$^{30}$Si (meas.)</th>
<th>$^{48}$Ti/$^{30}$Si (corr.)</th>
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### Spot 24: Sample TM783 – Area B

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<th>time (s)</th>
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<th>$^{48}$Ti/$^{30}$Si (meas.)</th>
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### Spot 25: Sample TM783 – Area B

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Standard Dev. (ppm): 0.43

### Spot 26: Sample TM783 – Area B

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<th>time (s)</th>
<th>$^{48}\text{Ti}$ counts</th>
<th>time (s)</th>
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<th>$^{48}\text{Ti}/^{30}\text{Si}$ (meas.)</th>
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<th>Ti (ppm)</th>
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Standard Dev. (ppm): 0.24
### Spot 27: Sample TM623 – Crenulations

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**Standard Dev. (ppm):** 0.16

### Spot 28: Sample TM623 – Crenulations

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**Standard Dev. (ppm):** 0.35
### Spot 29: Sample TM623 – Crenulations

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### Spot 30: Sample TM623 – Crenulations

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Standard Dev. (ppm):
## Spot 31: Sample TM623 – Crenulations

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<th>$^{48}$Ti/$^{30}$Si (meas.)</th>
<th>$^{48}$Ti/$^{30}$Si (corr.)</th>
<th>Ti (ppm)</th>
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Standard Dev. (ppm): 0.18

## Spot 32: Sample 09SD08A – Vein

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Standard Dev. (ppm): 0.17
## Spot 33: Sample 09SD08A – Vein

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**Avg.** 5.31E+05 2.83E+03 1.66E+02 5.35E-03 3.14E-04 3.04E-04 3.38

Standard Dev. (ppm): 0.22

## Spot 34: Sample 09SD08A – Matrix

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**Avg.** 4.91E+05 4.64E+03 2.21E+02 9.49E-03 4.50E-04 4.32E-04 4.81

Standard Dev. (ppm): 0.20
### Spot 35: Sample 09SD08A – Matrix

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**Standard Dev. (ppm): 0.23**

### Spot 36: Sample 09SD08A – Matrix

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**Standard Dev. (ppm): 0.26**
## Spot 37: Sample 09SD08A – Matrix

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<th>time (s)</th>
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<th>time (s)</th>
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<th>$^{46}$Ti/$^{30}$Si (corr.)</th>
<th>Ti (ppm)</th>
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## Spot 38: Sample 09SD08A – Matrix

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<th>$^{46}$Ti/$^{30}$Si (meas.)</th>
<th>$^{46}$Ti/$^{30}$Si (corr.)</th>
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Standard Dev. (ppm): 0.28
### Spot 39: Sample 09SD08A – Matrix

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*Standard Dev. (ppm): 0.36*

### Spot 40: Sample 09SD08A – Matrix

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*Standard Dev. (ppm): 0.18*
### Spot 41: Sample 09SD08A – Matrix

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Standard Dev. (ppm): 0.23

### Spot 42: Sample 09SD08A – Garnet Core

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Standard Dev. (ppm): 0.47
## Spot 43: Sample 09SD08A – Garnet Core

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Standard Dev. (ppm): 0.42

## Spot 44: Sample 09SD08A – Garnet Core

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Standard Dev. (ppm): 0.19
### Spot 45: Sample 09S08A – Garnet Core

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Standard Dev. (ppm): 0.33

### Spot 46: Sample 09S08A – Garnet Core 2

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Standard Dev. (ppm): 0.33
## Spot 47: Sample 09SD08A – Garnet Core 2

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## Spot 48: Sample 09SD08A – Garnet Core 2

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### Spot 49: Sample 09SD08A – Garnet Core 2

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Standard Dev. (ppm): 0.55

### Spot 50: Sample 09SD08A – Garnet Rim

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Spot 51: Sample 09SD08A – Garnet Rim

Spot 52: Sample 09SD08A – Garnet Rim
### Spot 53: Sample 09SD08A – Garnet Rim

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Standard Dev. (ppm): 0.26

### Spot 54: Sample 09SD08A – Garnet Ps

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Standard Dev. (ppm): 0.41
### Spot 55: Sample 09SD08A – Garnet Ps

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Standard Dev. (ppm): 0.30

### Spot 56: Sample 09SD08A – Garnet Ps

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Standard Dev. (ppm): 0.35
### Spot 57: Sample 09SD08A – Garnet Ps

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**Avg.** | **2.13E+05** | **2.10E+03** | **5.32E+01** | **9.60E-03** | **4.32E-04** | **4.14E-04** |

Standard Dev. (ppm): 0.39

### Spot 58: Sample 09SD08A – Garnet Ps

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**Avg.** | **1.21E+05** | **1.15E+03** | **1.09E+02** | **9.54E-03** | **9.00E-04** | **8.83E-04** |

Standard Dev. (ppm): 0.30
### Spot 59: Sample TM455 – Fold (SGR)

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Standard Dev. (ppm): 0.47

### Spot 60: Sample TM455 – Fold (SGR)

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Standard Dev. (ppm): 0.41
### Spot 61: Sample TM455 – Fold (SGR)

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<th>Ca/Si</th>
<th>Ti/Si</th>
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Standard Dev. (ppm): 0.42

### Spot 62: Sample TM455 – Fold (SGR)

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Standard Dev. (ppm): 0.52
### Spot 63: Sample TM455 – Garnet

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Standard Dev. (ppm): 0.27

### Spot 64: Sample TM455 – Garnet

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<th>time (s)</th>
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<th>time (s)</th>
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<th>$^{48}$Ti/$^{30}$Si (meas.)</th>
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Standard Dev. (ppm): 0.21
### Spot 65: Sample TM455 – Garnet

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**Standard Dev. (ppm):** 0.30

### Spot 66: Sample TM455 – Garnet

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**Standard Dev. (ppm):** 0.24
### Spot 67: Sample 10SD03D – Garnet Rim

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Standard Dev. (ppm): 0.22

### Spot 68: Sample 10SD03D – Garnet Rim

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Standard Dev. (ppm): 0.19
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Standard Dev. (ppm): 0.27
### Spot 71: Sample 10SD03D – Garnet Mat

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**Standard Dev. (ppm): 0.32**

### Spot 72: Sample 10SD03D – Garnet Mat

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**Standard Dev. (ppm): 0.44**
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**Standard Dev. (ppm): 0.39**

### Spot 74: Sample 10SD03D – Garnet Inc3

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**Standard Dev. (ppm): 0.20**
**Spot 75: Sample 10SD03D – Garnet Inc3**

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**Spot 76: Sample 10SD03D – Garnet Inc3**

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### Spot 77: Sample 10SD03D – Garnet Inc6

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Standard Dev. (ppm): 0.36

### Spot 78: Sample 10SD03D – Garnet Inc6

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Standard Dev. (ppm): 0.33
### Spot 79: Sample 10SD03D – Garnet Inc5

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Standard Dev. (ppm): 0.31

### Spot 80: Sample 10SD03D – Garnet Inc5

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Standard Dev. (ppm): 0.36
### Spot 81: Sample 10SD03D – Garnet Inc5

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**Standard Dev. (ppm): 0.30**

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### Spot 82: Sample 10SD03D – Garnet Inc5

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**Standard Dev. (ppm): 0.32**
Spot 83: Sample 10SD03D – Garnet Inc4

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Standard Dev. (ppm): 0.33

Spot 84: Sample 10SD03D – Garnet Inc4

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Standard Dev. (ppm): 0.40
Spot 85: Sample 10SD03D – Garnet Inc4

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Standard Dev. (ppm): 0.35

Spot 86: Sample 10SD03B2 – Garnet Inc8

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Standard Dev. (ppm): 0.36
## Spot 87: Sample 10SD0382 – Garnet Inc8

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## Spot 88: Sample 10SD0382 – Garnet Inc8

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### Spot 89: Sample 10SD0382 – Garnet Inc8

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Standard Dev. (ppm): 0.43

### Spot 90: Sample 10SD0382 – Garnet Inc7

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Standard Dev. (ppm): 0.60
### Spot 91: Sample 10SD03B2 – Garnet Inc7

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Standard Dev. (ppm): 0.60

### Spot 92: Sample 10SD03B2 – Garnet Inc7

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Standard Dev. (ppm): 0.65
### Spot 93: Sample 10SD03B2 – Garnet Inc7

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Standard Dev. (ppm): 0.54

### Spot 94: Sample 10SD03B2 – Garnet Inc4

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Standard Dev. (ppm): 0.63
### Spot 95: Sample 10SD0382 – Garnet Inc4

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Standard Dev. (ppm): 0.40

### Spot 96: Sample 10SD0382 – Garnet Inc4

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Standard Dev. (ppm): 0.47
### Spot 97: 10SD03B2 – Garnet Inc4

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<td>3.36E+02</td>
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<td>3.56E+02</td>
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<td>Avg.</td>
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<td>2.88E+03</td>
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<td>Standard Dev. (ppm): 0.47</td>
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