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STRUCTURE AND PETROLOGY AT THE LEADING EDGE OF THE WILSON LAKE TERRANE, CENTRAL LABRADOR

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ABSTRACT

The Wilson Lake terrane, central Labrador, is a composite tectonic unit consisting of the high-grade Red Wine Mountains massif (RWMM), forming the upper structural domain, and lower grade gneiss, which makes up the lower structural domain. Metamorphism and regionally persistent penetrative deformation in the RWMM are inferred to be associated with Labradorian orogenesis, whereas evidence for Grenvillian metamorphism and structures in the terrane are sparse.

The RWMM is separated from lower grade rocks of the Churchill Falls terrane by the Allochthon Boundary Thrust, which is well-exposed along the East Metchin River as a ductile mylonite. Field and petrologic studies that focused on the RWMM indicate a complex Labradorian history of structural and metamorphic events that predated tectonic emplacement over the lower structural unit. Work in 2003 has shown that the Metchin River mylonite, at the base of the RWMM, also records a complex history. The mylonite is divided into 2 zones that are distinguished by structural style. The upper zone has been subjected to at least one folding event about northeast-trending axes. An array of undeformed pegmatite dykes are parallel to the axial surfaces of these folds. The folds can be followed continuously into a lower, more complicated zone where two fold episodes are apparent, and where sillimanite rather than kyanite is the predominant aluminosilicate. The earliest folds in this zone trend north–south, and an array of pegmatite dykes are parallel to these fold traces. The folds and undeformed pegmatite dykes are at a high angle to the Allochthon Boundary Thrust and may be truncated by it. Field relationships demonstrate that pegmatite emplacement is the youngest event in the Metchin River mylonite.

Petrologic evidence suggests that the RWMM records a history of isobaric cooling during the Labradorian Orogeny, consistent with tectonically stable continental crust that has achieved isostatic equilibrium. In the absence of additional age constraints, it remains possible that the Metchin River mylonite is older than Grenvillian and unrelated to the emplacement of the RWMM, but more closely related to the emplacement of the larger Wilson Lake terrane.

INTRODUCTION

The Wilson Lake terrane of central Labrador is one of several allochthonous, thrust-bound crustal segments that characterize the eastern Grenville Province (*see* Rivers *et al*., 1989; Gower, 1996). The allochthons include the Lac Joseph terrane to the west and the Mealy Mountains terrane to the east of the Wilson Lake terrane. These allochthonous slices are generally distributed parallel to the Grenville front and are separated from it by the Trans-Labrador batholith for a distance of nearly 600 km (Figure 1).

The northwestern part of the Wilson Lake terrane, in the Wilson Lake area, consists of two domains defined primarily on the basis of metamorphic grade and magnetic signature (Figure 1). One domain, the Red Wine Mountains massif (RWMM) (Thomas, 1993), is composed of high-grade migmatitic gneiss. The massif underlies the highlands of the Red Wine Mountains, a prominent east-northeast range that extends for more than 100 km. The RWMM is characterized by a pronounced, regional magnetic high (Figure 2). The other domain is composed of lower grade rocks that characterize the Wilson Lake terrane south and east of the RWMM. In contrast to the high-grade rocks of the massif, the lower grade rocks have a relatively low magnetic expression (Figure 2). The western boundary of the RWMM is a ductile shear zone that also defines the tectonic boundary of the Wilson Lake terrane with the adjacent Churchill Falls terrane (Figure 1). The lower grade rocks that underlie the massif to the north and west are part of the Churchill Falls terrane.

Previous geochronological studies in the Wilson Lake terrane date a high-grade metamorphic event to Labradorian

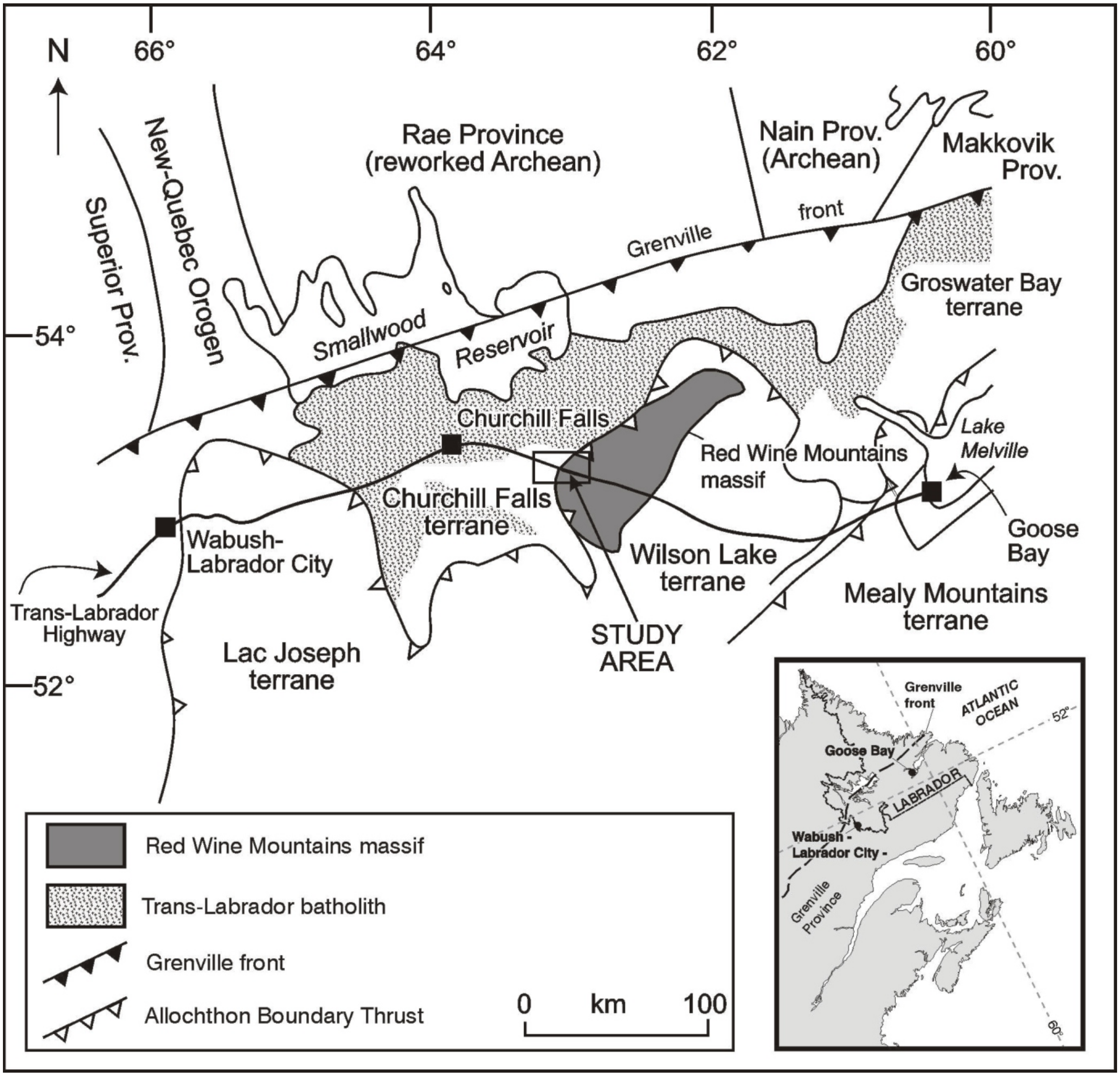

Figure 1. *Structural subdivision of the eastern Grenville Province in central Labrador after Corrigan* et al. *(1997) and location of the study area. The study area is in the Wilson Lake terrane, which consists of two domains defined primarily on the basis of metamorphic grade and magnetic signature. One domain is the Red Wine Mountains massif (dark grey), composed of high-grade migmatitic gneiss. The other domain is composed of lower grade rocks (unshaded) that characterize the Wilson Lake terrane south and east of the massif.*

orogenesis (1710 to 1600 Ma) (e.g., Currie and Loveridge, 1985; Nunn *et al*., 1985; Thomas *et al*., 1986; Gower, 1996; Corrigan *et al.*, 1997; Gross *et al.*, 2003). Tectonic emplacement of the Wilson Lake terrane is considered to have been a short-lived event associated with Grenvillian orogenesis (1010 to 990 Ma) (Corrigan *et al*., 1997; Gower and Krogh, 2002), although evidence for Grenvillian metamorphism in the terrane is sparse (Gower and Krogh, 2002).

The broad goals of this study are to better characterize the conditions and timing of metamorphism and deformation in the Wilson Lake terrane, and to understand how the RWMM may have responded to tectonic emplacement. An important aspect of this study is to understand the evolution of the RWMM. Do the two domains in the Wilson Lake terrane represent separate crustal blocks with different metamorphic histories that were subsequently assembled during either Labradorian or Grenvillian orogenesis, or was the terrane assembled during Labradorian orogenesis and unevenly overprinted during a Grenvillian event? In order to address these questions, fieldwork completed in 2002 concentrated on sample collection and analysis of the high-grade metamorphic assemblages of the RWMM. Results of that study are given in Korhonen and Stout (2003, *in press*). During the 2003 field season, a portion of the ductile shear zone that separates the RWMM from the lower grade Churchill Falls terrane along the East Metchin River was mapped. This report summarizes some results from these studies.

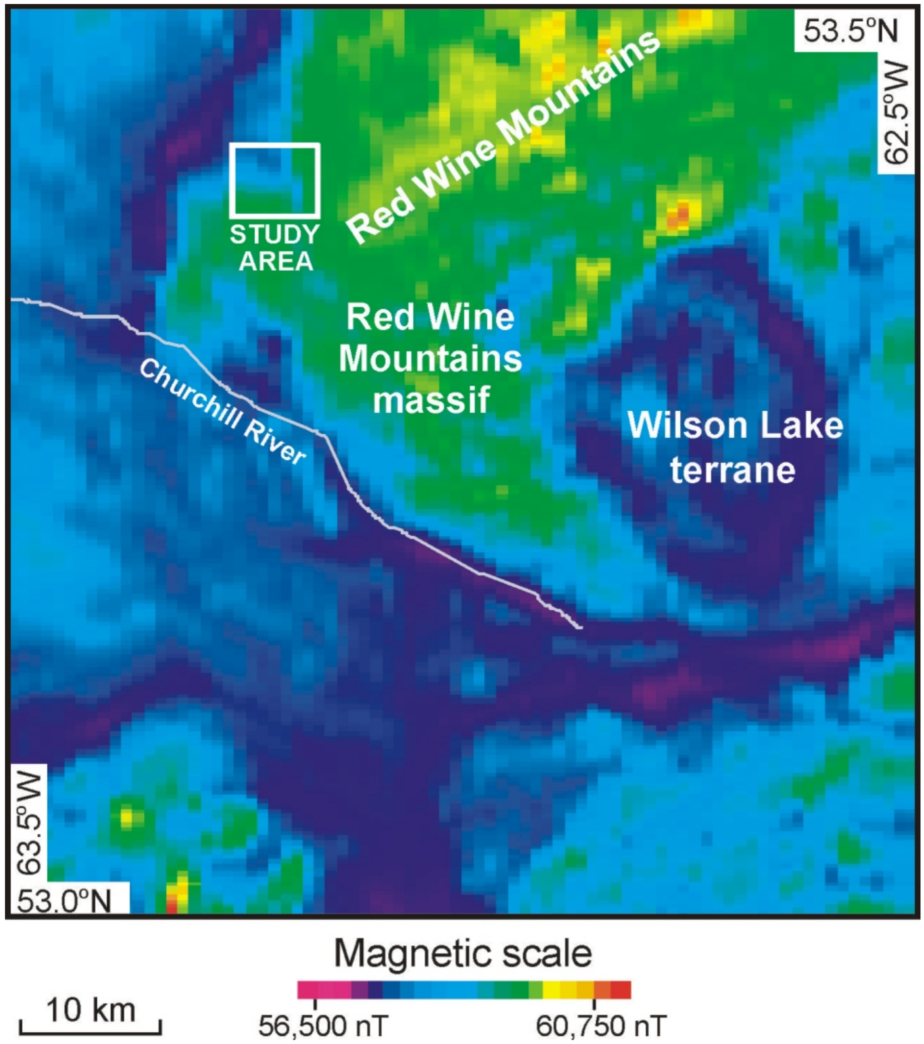

Figure 2. *Aeromagnetic map for the Wilson Lake terrane (from the Geophysical Data Centre, Geological Survey of Canada, Ottawa).*

REGIONAL AND LOCAL GEOLOGY

The rocks that make up the Wilson Lake terrane are dominantly migmatitic quartzofeldspathic gneiss referred to as the Disappointment Lake paragneiss (Thomas, 1993; Thomas *et al*., 2000). Arima *et al.* (1986) infer a sedimentary parentage based on relatively high whole-rock oxygen isotopic compositions and similarities of major and trace elements with average post-Archean shales. Further support for a sedimentary protolith is the occurrence of minor marble and quartzite locally interlayered with the Disappointment Lake paragneiss (e.g., Thomas *et al.*, 2000).

The granulite-grade paragneiss in the RWMM is exceptionally hard and dense, resists breakage across foliation, and commonly lacks hydrous minerals. The most distinctive mineral assemblages are orthopyroxene + sillimanite + quartz, and sapphirine + quartz. Exsolved titanhematite and pure magnetite are nearly ubiquitous and commonly constitute up to several percent of the rocks. These assemblages are found within the restitic layers of the paragneiss and are widespread in the massif (Morse and Talley, 1971; Arima *et al*., 1986; Currie and Gittens, 1988). The exsolved titanhematite carries a strong stable magnetic remanence and is responsible for the observed aeromagnetic high (Kletetschka and Stout, 1998). This paragneiss is highly deformed and exhibits at least two periods of isoclinal folding (Thomas, 1993; Thomas *et al.*, 2000).

The RWMM includes bodies of deformed medium-grained gabbronorite. Many of these bodies cut across the paragneiss foliation and a few of them exhibit fine-grained margins typical of dykes. Spectacular outcrops along a new section of the Trans-Labrador Highway (e.g., 500007 E, 5909845 N) reveal at least two generations of these dykes. Undeformed fine-grained mafic dykes (501481 E, 5908893 N) and coarse-grained pegmatite dykes (498648 E, 5910151 N) are also well-exposed along this new section of highway.

The lower grade rocks surrounding the RWMM are middle to upper amphibolite-facies paragneiss. The lower grade gneiss is distinguished from the high-grade gneiss by the ubiquitous presence of muscovite and/or biotite, and the absence of sapphirine (Thomas *et al*., 2000). These rocks split readily along their micaceous foliation. Sillimanite and/or kyanite, garnet, and cordierite are also common. Herd *et al*. (1987), Currie and Gittens (1988), and Thomas

(1993) interpreted the cordierite and other hydrous phases as indicative of an amphibolite-facies event inferred to be of Grenvillian age.

Experimental studies (Hensen and Green, 1971; Bertrand *et al.*, 1991) in the ideal FeO–MgO–Al_2O_3–SiO_2 (FMAS) system indicate extremely high temperatures (>1000° C) and moderate pressure (>1000 MPa) for the assemblages in the RWMM. These studies and the geochronological data summarized above suggest that much of the RWMM was subject to extremely high-temperature metamorphism during Labradorian orogenesis. The absence of pervasive Grenvillian overprinting has been interpreted by others (e.g., Arima *et al*., 1986; Corrigan *et al.*, 1997) as evidence for cold tectonic emplacement over the lower grade rocks, possibly during Grenvillian orogenesis.

The boundary between the Wilson Lake and the Churchill Falls terranes is the Allochthon Boundary Thrust (ABT), a first-order tectonic boundary (Rivers *et al*., 1989). The ABT is well-exposed along the East Metchin River as a ductile mylonite. The rocks in the mylonite are quartzofeldspathic paragneiss having common garnet + kyanite ± sillimanite assemblages. Numerous pegmatite dykes intrude the mylonite and crosscut the foliation. A single preliminary U–Pb age of 990 ± 2 Ma on monazite from one such pegmatite has been interpreted by Corrigan *et al.* (1997) to provide a minimum age of tectonic displacement. No data have yet been published with age constraints directly from this shear zone. Similar Grenvillian ages have been obtained from pegmatites in other localities with the interpretation that emplacement of the dykes was syn-deformation. A pegmatite in the shear zone separating the Wilson Lake and the Mealy Mountains terranes to the southeast (Figure 1) yielded a monazite age of 1014 ± 4 Ma (Corrigan *et al*., 1997). A pegmatite from a ductile shear zone exposed in the Lac Joseph terrane west of the Wilson Lake terrane (Figure 1) has a monazite age of 999 +5/-3 Ma (Connelly and Heaman, 1993).

Constraints on the protolith ages and timing of metamorphism of the Wilson Lake terrane are sparse. Currie and Loveridge (1985) obtained a U–Pb upper concordia intercept age of 1699 ± 3 Ma on zircon from paragneiss from the RWMM. They interpret this age as that of the granulite-facies metamorphism. Biotite from the same specimen yielded a Rb–Sr date of 1014 ± 31 Ma, which they interpret as a retrograde, Grenvillian thermal event. Three monazite grains from sapphirine-bearing gneiss in the RWMM yield a concordant $^{207}Pb/^{206}Pb$ age of 1639 ± 1 Ma and 2 discordant ages of 1635 ± 3 Ma and 1640 ± 5 Ma (Corrigan *et al*., 1997). These authors attribute these ages to the waning stages of ultra high-grade Labradorian metamorphic conditions.

Monazite from a sapphirine-bearing sample collected from the RWMM during the 2002 field season support these Labradorian ages. Electron microprobe dating of six monazite cores yield ages ranging from 1652 ± 5 Ma to 1596 ± 12 Ma (Gross *et al*., 2003). Rim compositions were somewhat younger, ranging from 1563 ± 10 Ma to 1502 ± 17 Ma. Monazite from an orthopyroxene-bearing paragneiss, as part of the same study, gave similar core and rim ages.

U–Pb zircon dates from foliated orthogneiss, which intrudes paragneiss in the southern portion of the Wilson Lake terrane, give an igneous emplacement age of 1650 Ma (James *et al.*, 2002). The lower intercept age based on these data is poorly constrained, but suggests a Grenvillian overprinting event between 1080 and 1000 Ma. Rb–Sr dates on biotite from the Wilson Lake terrane are interpreted to date a retrograde event associated with Grenville emplacement and uplift (Currie and Loveridge, 1985; Thomas, 1993).

Some additional age constraints are provided in the Lac Joseph terrane. Both the Lac Joseph and the Wilson Lake terranes are part of the allochthonous belt of Rivers *et al.* (1989) and have been collectively referred to as the Western Labrador terranes based on similar tectonothermal histories (Gower and Krogh, 2002). The rocks in the Lac Joseph terrane are mainly amphibolite- to granulite-facies migmatites that exhibit two distinct generations of leucosomes (Connelly and Heaman, 1993). Monazite from these leucosomes yield U–Pb ages of 1660 and 1636 Ma, which are interpreted by Connelly and Heaman (1993) as crystallization ages of partial melting during protracted Labradorian orogenesis.

RED WINE MOUNTAINS MASSIF

MINERAL ASSEMBLAGES

Paragneiss

The high-grade paragneiss that characterizes the RWMM is typically migmatitic with alternating restitic and leucosome layers. Restite layers commonly contain sillimanite, orthopyroxene, biotite, titanhematite ± magnetite, and locally abundant sapphirine, garnet, and sporadically cordierite. Leucosomes range from a few millimetres in width, as part of the migmatitic foliation, to tens of centimetres in width. The wider leucosomes often form anastomosing veins that crosscut the migmatitic foliation. Leucosomes generally contain quartz, K-feldspar, plagioclase, and minor biotite, and have a general granoblastic texture. Some leucosomes contain large grains of orthopyroxene and aggregates of titanhematite up to 1 cm across. Titanhematite ± magnetite are also concentrated as deformed lenses and boudin-shaped masses up to tens of metres long and a few metres wide with relatively minor amounts of sapphirine, orthopyroxene, and spinel.

Several petrologic studies (Morse and Talley, 1971; Leong and Moore, 1972; Jackson and Finn, 1982; Currie and Gittens, 1988; Korhonen and Stout, *in press*) of paragneiss in the RWMM have focused on the silicate assemblages sapphirine + quartz, and orthopyroxene + sillimanite + quartz. Numerous samples collected during the 2002 field season contain these high-temperature assemblages (Plate 1). With two exceptions, sillimanite is the only Al_2SiO_5 polymorph described in previous studies, which is consistent with our own observations both in the field and in about 150 thin sections. Morse and Talley (1971) describe kyanite with sapphirine + quartz from a ridge 2 km north of the eastern part of Wilson Lake. This identity was recently confirmed by S.A. Morse (personal communication, 2002). The other exception is at the western margin of the massif as described below.

The rocks in the Wilson Lake terrane and especially in the RWMM show abundant evidence for having equilibrated under conditions of high-oxygen fugacity (fO_2) (Arima *et al*., 1986; Herd *et al.*, 1987; Korhonen and Stout, *in press*). Coexisting titanhematite and pure magnetite are pervasive throughout the terrane, indicating that the rocks equilibrated at an fO_2 slightly below that defined by the pure hematite and magnetite buffer. Further evidence of high fO_2 is exsolved titanhematite in orthopyroxene, exsolved hematite in sillimanite, exsolved magnetite in spinel, and high dissolved Fe^{3+} in many of the phases, including sillimanite and corundum. Many samples from the RWMM contain assemblages having silicate and oxide phases that appear to have achieved textural equilibrium as determined petrographically. These phases also display a systematic partitioning of elements based on microprobe analyses, further support that the coexisting silicates and oxides attained chemical equilibrium (Korhonen and Stout, *in press*).

The pronounced aeromagnetic high of the RWMM (Figure 2) is caused by a strong, stable remanence carried by host titanhematite in exsolved primary grains (Kletetschka and Stout, 1998). Lesser amounts of titanhematite in the lower grade rocks account for the aeromagnetic low (Figure 2). Because the remanence was acquired during cooling, it must postdate the primary metamorphism and is a relatively late feature. The presence of undeformed exsolution lamellae in deformed grains associated with ductile shear zones further suggests that the remanence was acquired post-deformation (Korhonen and Stout, *in press*), although the timing of deformation is uncertain.

The relatively high fO_2 metamorphic conditions experienced in the RWMM has important effects on phase equilibria and mineral stability fields. The ideal FMAS system can be used to assess pressure (P)-temperature (T) paths (Figure 3). Arima *et al.* (1986) and Currie and Gittens

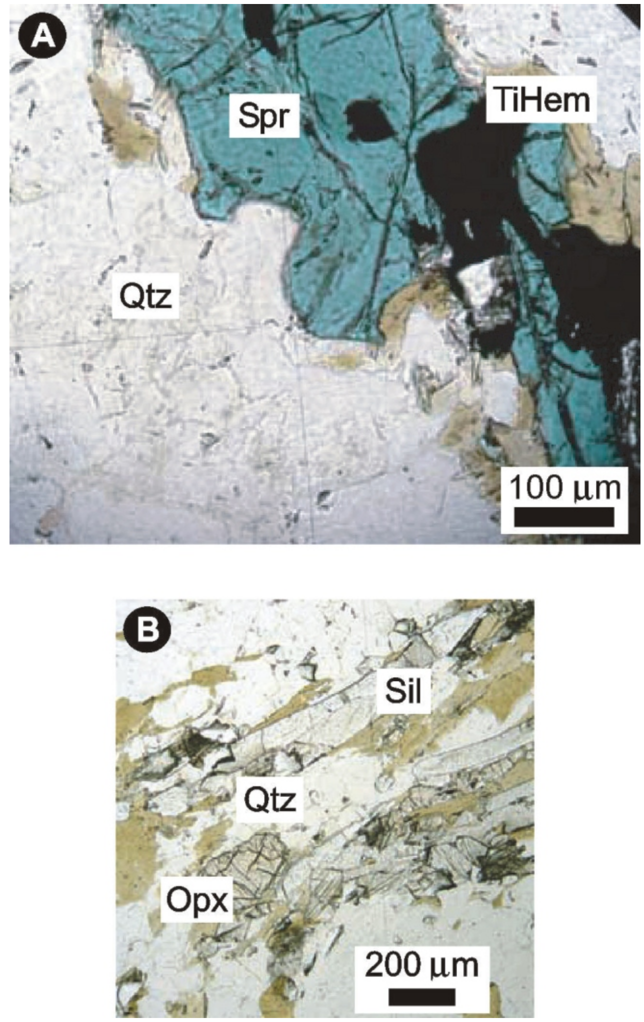

Plate 1. *Characteristic high-temperature assemblages in the Red Wine Mountains massif: (A) sapphirine (Spr) + quartz (Qtz); (B) orthopyroxene (Opx) + sillimanite (Sil) + Qtz. Titanhematite (TiHem) is closely associated with these assemblages and indicates that the granulite-facies metamorphism occurred under conditions of high-oxygen fugacity.*

(1988) have used the FMAS system to interpret P–T paths in the RWMM. A rigorous discussion of the effects of high fO_2 on the FMAS system is beyond the scope of this paper, although existing studies can be confidently interpreted to show that the partial petrogenetic grid in the ideal FMAS system is not satisfactory for interpreting these rocks for two reasons (Korhonen and Stout, *in press*). First, the phase compositions in the RWMM depart from the FMAS system. Additional components, including Fe_2O_3, TiO_2, ZnO, and H_2O, are necessary to accurately describe the phase equilibria from which accurate pressures and temperatures are derived. Moreover, the oxides are important phases in these rocks and need to be included in any petrologic analysis.

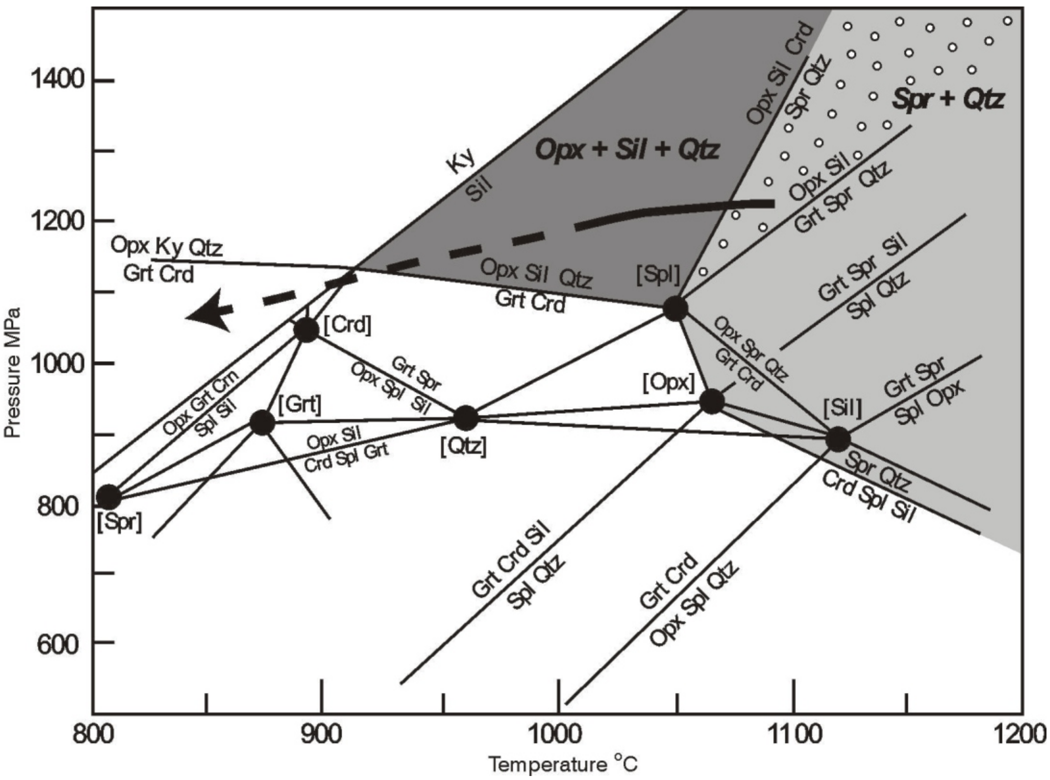

Figure 3. *Partial FeO-MgO-Al_2O_3-SiO_2 (FMAS) petrogenetic grid modified after Hensen (1987); Hensen and Harley (1990); Spear (1995). The stability field for Spr + Qtz is light grey; the stability field for Opx + Sil + Qtz is dark grey; the overlapping stability field for Spr + Qtz + Opz + Sil is light grey with circles. Assemblages from the Wilson Lake terrane suggest an isobaric cooling P–T path.*

Second, the partial petrogenetic grid in Figure 3 may be unsatisfactory because it applies to P–T stabilities under relatively low fO_2 conditions. There is no equivalent grid to Figure 3 that applies to the P–T–fO_2 conditions that existed in the rocks from the RWMM. A qualitative evaluation of the phase equilibria in the RWMM indicates that previous P–T estimates may be too high (Korhonen and Stout, *in press*).

Most rocks in the RWMM appear to have preserved primary high-grade assemblages, whereas some assemblages show evidence for disequilibrium and variable overprinting. Petrographic observations of some rocks reveal undeformed coronas of secondary orthopyroxene, cordierite, and sillimanite separating sapphirine and quartz. Such non-equilibrium textures and reaction rims have been described in rocks from Wilson Lake (e.g., Morse and Talley, 1971; Leong and Moore, 1972; Grew, 1980; Arima *et al.*, 1986; Currie and Gittens, 1988; Korhonen and Stout, *in press*). This texture is indicative of the retrograde reaction sapphirine + quartz = orthopyroxene + sillimanite + cordierite. Orthopyroxene rims in these coronas have a composition consistent with crystallization at less oxidizing conditions than the orthopyroxene that appears to be part of the primary assemblages (Korhonen and Stout, *in press*).

Samples from the leading edge of the RWMM 3 km to the east of the Metchin River mylonite are distinctive in that they lack orthopyroxene and/or sapphirine. Instead, these samples have the assemblages kyanite + sillimanite + garnet, and kyanite + cordierite + garnet, both with biotite, exsolved titanhematite, quartz, and feldspars (Plate 2). Sillimanite in these rocks is sparse, occurring as isolated prisms surrounded by abundant finer grained, euhedral kyanite. These assemblages represent lower temperatures than those generally formed in the RWMM.

Mafic Dykes

The oldest mafic dykes in the RWMM cut across the paragneiss foliation and range in thickness from one to sev-

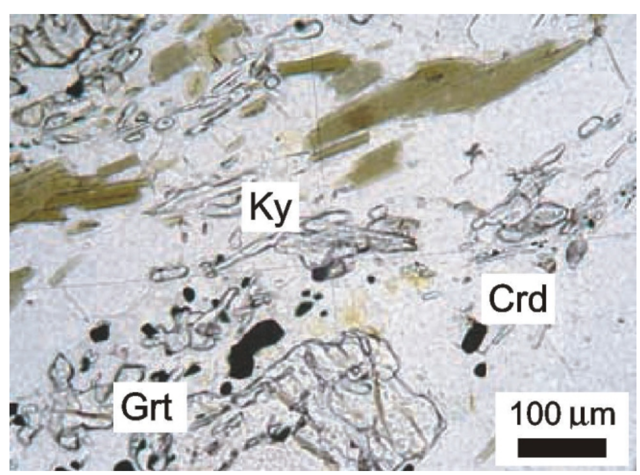

Plate 2. *Photomicrograph from the leading edge of the Wilson Lake terrane with kyanite (Ky) + cordierite (Crd) + garnet (Grt). This assemblage is stable at lower temperatures than the high-grade assemblages from the Red Wine Mountains massif.*

eral metres. The dykes generally trend east–west and are steeply dipping. Individual dykes show few signs of internal deformation in the field although their broader distribution indicates that they are folded (*see* Currie and Gittens, 1988; Thomas *et al*., 2000). They exhibit little to no mineral fabric and the gradation from coarser grained centres to finer grained margins is commonly preserved. The dykes consist mainly of 2 pyroxenes and plagioclase in about equal amounts, which give the rocks a distinctive salt and pepper appearance. Some of these dykes contain up to about 10% titanhematite, and minor felsic lenses may represent the product of anatexis. Biotite and magnetite are less abundant. These observations are consistent with the dykes having been metamorphosed to granulite facies. Hornblende is not common, but where present appears to be a product of late-stage hydration.

A different generation of mafic dykes also cuts across paragneiss foliation. These dykes are not abundant, but are easily recognized by their high biotite content and distinctive schistosity, which runs subparallel to the dykes. Evidence of this fabric in the adjoining paragneiss is restricted to a faint crenulation cleavage within a 1 m zone of the dykes. Plagioclase, quartz, titanhematite, rutile, and fine, euhedral garnet are also present.

The youngest mafic intrusions in the RWMM are fine-grained, east-trending dolerite dykes that have shallow to horizontal dips, and appear to be unmetamorphosed. They are planar, up to 1 m thick and taper to zero thickness over distances of a few tens of metres. A distinctive feature of these dykes in the field is a pervasive orthogonal jointing spaced tens of centimetres apart.

Felsic Intrusions

Two types of felsic intrusions have been examined in the RWMM. Coarse-grained, undeformed pegmatites up to several tens of metres in width are exposed along a new section of the Trans-Labrador Highway (498648 E, 5910151 N). K-feldspar crystals up to1 m wide and large radial sprays of biotite and muscovite are distinctive. Smokey quartz, tourmaline, lepidolite, and bluish prisms of apatite up to 10 cm long are noteworthy. Undeformed contacts with paragneiss and mafic dykes and preservation of primary igneous/hydrothermal textures indicate that these dykes are unmetamorphosed, undeformed, and on this basis, are likely late syn- to post-Grenvillian intrusions.

A second type of felsic dyke consists of pegmatitic seams that rarely exceed 1 cm in width. They are remarkably planar, extending as much as 10 m along strike until they pinch out. They consist of perthite, plagioclase, quartz, and minor amounts of tourmaline and dumortierite, an aluminous boro-silicate mineral. Notably, they also contain euhedral laths of kyanite.

METCHIN RIVER SHEAR ZONE

The high-grade rocks of the RWMM are separated from the underlying lower grade rocks of the Churchill Falls terrane by the Allochthon Boundary Thrust (ABT; Figure 1) (Rivers *et al*., 1989; Corrigan *et al*., 1997). The ABT is well-exposed along strike parallel to the East Metchin River from at least 1 km north of the Trans-Labrador Highway bridge and downstream 1.5 km to the confluence with the Metchin River (Figure 4). In this area, the ABT consists of intensely mylonitized quartzofeldspathic rocks. Glacial drift covers the contact between the mylonite and the RWMM to the southeast. To our knowledge, these rocks have only been described in a preliminary report by Corrigan *et al.* (1997), although Thomas (1993) identifies mylonitic zones in this general area. Here, the mylonite is divided into 2 domains that are distinguished by structural style: an upper domain (Zone A), and a more complex lower domain (Zone B) (Figure 5).

UPPER UNIT (ZONE A)

The mylonite in Zone A is distinctive in outcrop (Plate 3), consisting of fine quartzofeldspathic laminations punctuated by feldspar porphyroclasts up to 1 cm in diameter. The porphyroblasts are commonly elongated in some outcrops and, when developed, define a consistent lineation that is easily recognized in the field. Sense of shear on rotated porphyroclasts was determined unambiguously in the field from 6 different localities as top to the north (4 examples) and top to the northwest (2 examples). Axes of rotation are roughly normal to the lineation. The Zone A mylonite also includes rare boudins of orthopyroxenite.

The mylonite in Zone A is generally dipping to the northeast (under the Red Wine Mountains massif) and is gently deformed into northeast-trending folds. Analyses of individual folds reveal that fold axes are shallowly plunging and axial surfaces have a shallow dip. The resulting asymmetry is not always apparent in the field because commonly only the symmetric tops of folds are exposed. Poles to foliation in Zone A show a broadly defined girdle having a pronounced maximum that reflects the prevailing northeasterly dipping limbs of the folded mylonite (Figure 5). The lesser maxima in the girdle reflect the less abundant opposite fold limbs. This distribution indicates a general fold axis trending northeast, which is consistent with the distribution of hinge line measurements on individual folds. Mineral lineations in Zone A mylonite are typically oriented northeast, but there is also a lesser population trending east–southeast (Figure 5). Mineral lineations are folded, but reconstruction of the original orientations is complicated by multiple deformation events.

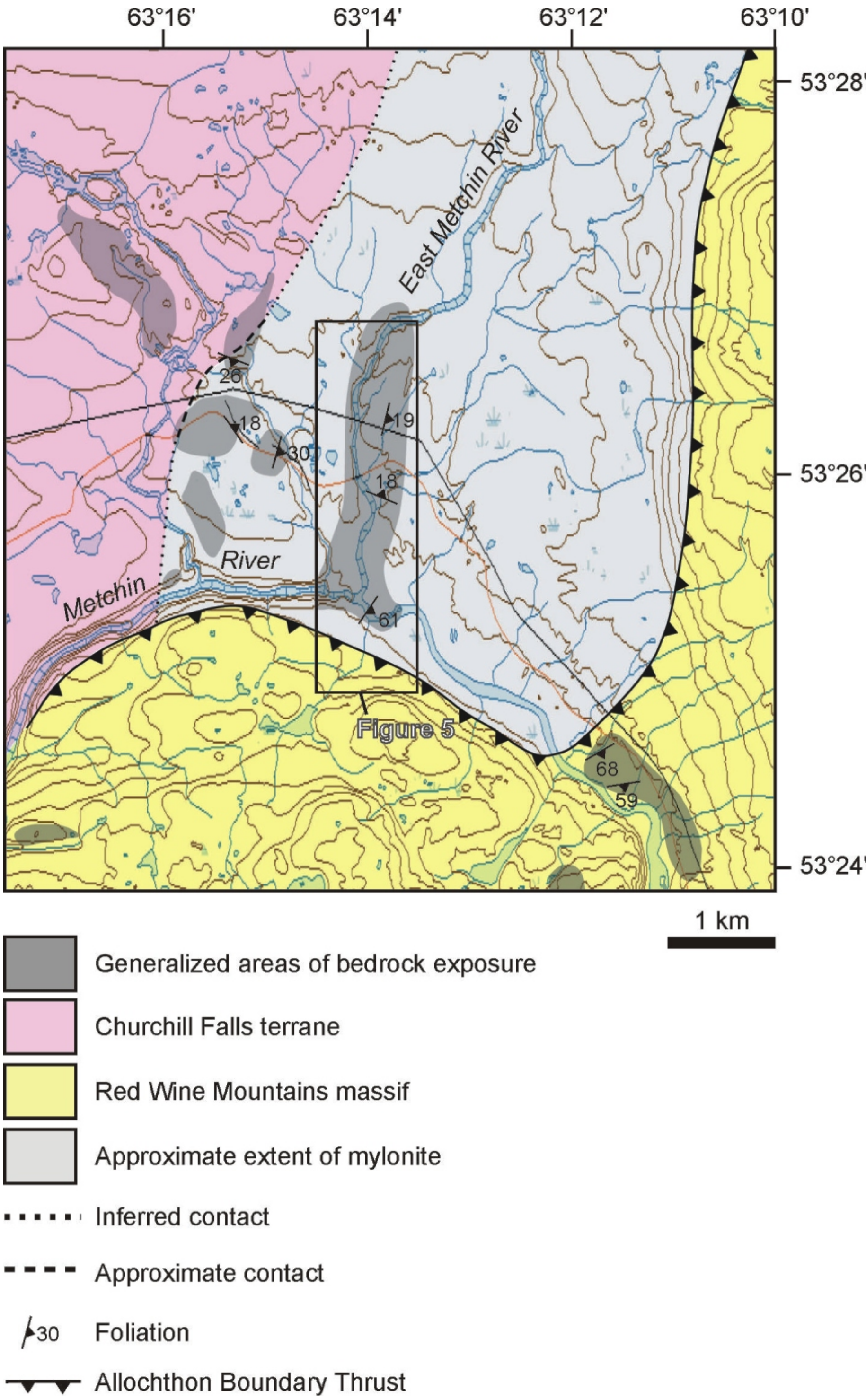

Figure 4. *Simplified structural map within the Metchin River shear zone mapped in 2003. Representative field data are shown. Location of the Allochton Boundary Thrust (ABT) modified after Thomas (1993).*

Microscopically, porphyroclasts in Zone A mylonite consist of microperthite and plagioclase set in a fine-grained matrix of quartz, biotite, kyanite, and garnet (Plate 4). Titan-hematite, magnetite, and monazite are ubiquitous accessories. The monazite is commonly zoned, and in one case is rotated in a finer grained matrix of quartz, biotite, and kyanite. One thin section revealed minor sillimanite along with kyanite. The plagioclase porphyroclasts exhibit internal deformation in the form of curved twin planes. Many porphyroclasts are mantled by finer, equidimensional feldspar and some porphyroclasts are completed recrystallized to polygonal aggregates (Plate 4). Bladed kyanite is abundant, fine grained (average 100 µm in length), and commonly crenulated.

An extensive array of pegmatite dykes having consistent northeast trends intrude the Zone A mylonite (Figure 5). These dykes are commonly zoned with quartz and muscovite-rich centres and margins comprised of elongate euhedral feldspars up to several centimetres in length that have grown normal to the dyke contact (Plate 5). Garnet has been observed in some pegmatites, although not in all. The dykes have sharp contacts with the adjacent mylonite and in a few cases occupy the disrupted axial surfaces of small folds. The dykes are unequivocally undeformed and unmetamorphosed. The field relationships demonstrate that pegmatite emplacement is the youngest event in the Metchin River mylonite.

LOWER UNIT (ZONE B)

The Zone B mylonite is typically finer grained than the Zone A mylonite but is still characterized by lineated feldspar porphyroclasts scattered throughout a laminated matrix. Unlike Zone A mylonite, the matrix commonly contains lineated sillimanite and possibly cordierite. Like Zone A, there are boudins of pyroxenite.

The Zone B mylonite shows evidence for more complicated folding in at least two directions. There is a well-exposed section of this zone at the confluence of the East Metchin River and the Metchin River (484160 E,

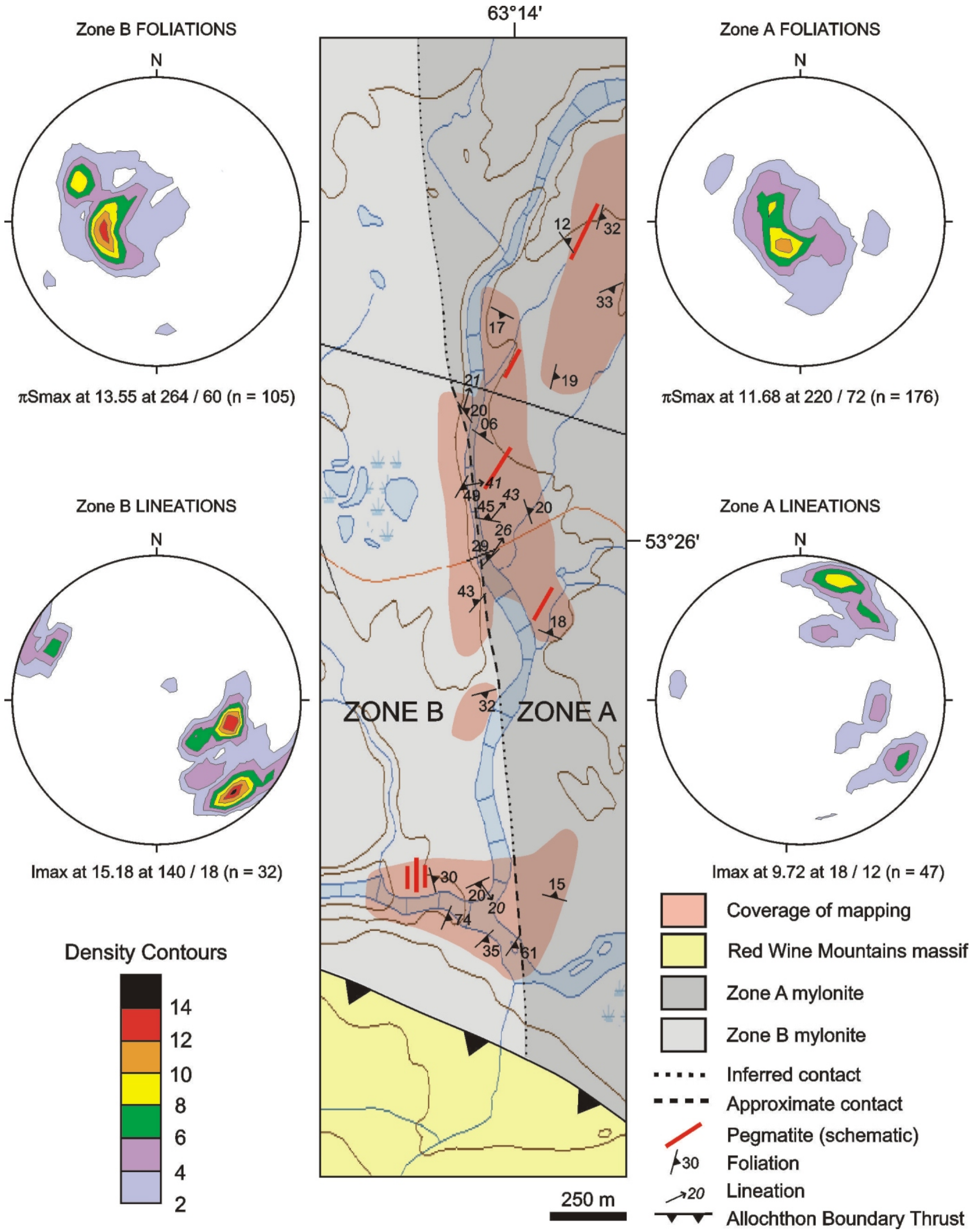

Figure 5. *Detailed structural map from the Metchin River shear zone delineating Zone A and Zone B mylonite. Equal area lower hemisphere projections of poles to foliation and lineation for Zone A and Zone B are also shown.*

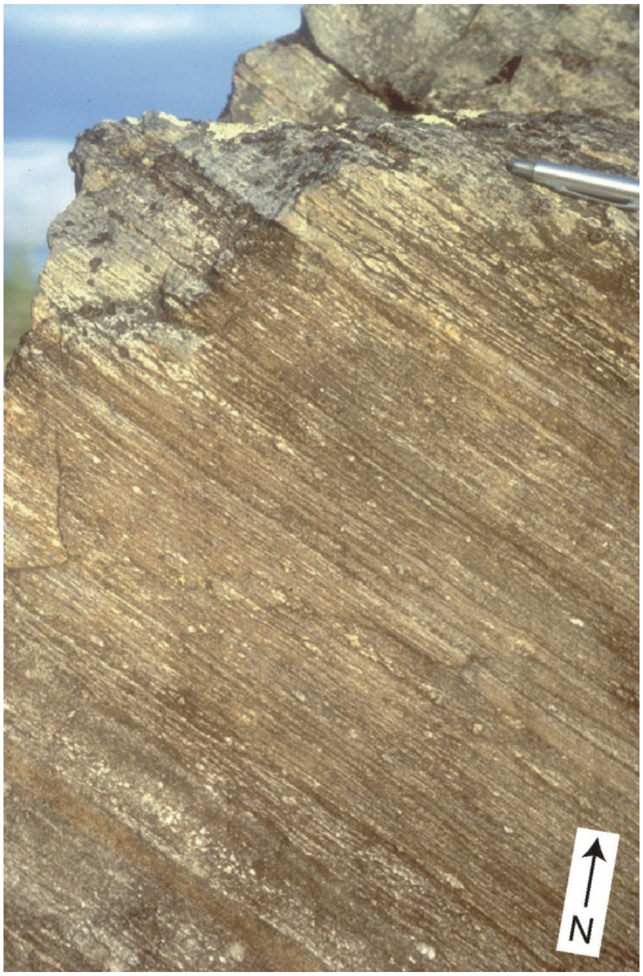

Plate 3. *Zone A mylonite having fine quartzofeldspathic laminations punctuated by K-feldspar porphyroclasts up to 1 cm in diameter. Photograph of vertical face looking N-NW.*

5919360 N). The dominant folds are symmetric and upright with limbs dipping as steeply as 70°. Sillimanite lineations are clearly folded. The limbs of these folds exhibit significant thinning and shearing, and thickening in fold hinges (Plate 6). Amplitudes of these folds generally decrease toward the boundary with the Zone A mylonite. The direction of folding is generally north–south, but hinge lines dip variably to the north and south because of a later folding about a northeast-trending axis. The result is a distinctive interference fold pattern of domes and depressions that is well-exposed at this locality (Plate 7). Plotting of all foliations in Zone B shows a bimodal distribution (Figure 5), typically steeper than foliations in Zone A. Lineations also show a complex distribution (Figure 5), which is consistent with multiple folding.

An array of undeformed pegmatite dykes having similar mineralogy to those in Zone A trend north–south (Figure 5). These pegmatites are parallel with the thinned and sheared limbs of the earlier folds, and in many places occupy the fold hinges (Plate 8). Northeast-trending pegmatites, as observed in the upper zone, are generally not observed in the lower zone.

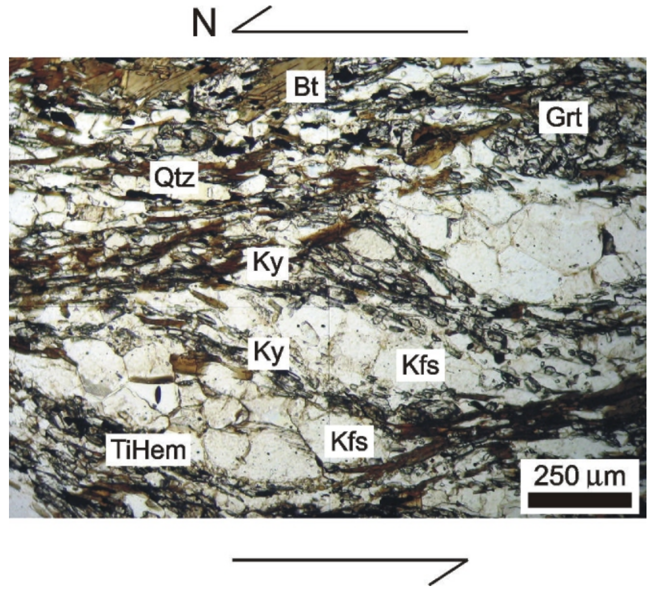

Plate 4. *Photomicrograph from the Metchin River mylonite (Zone A) with Ky + Grt + Qtz + TiHem + biotite (Bt) + K-feldspar (Kfs). Section is oriented perpendicular to foliation and parallel to lineation. Recrystallized porphyroclasts of Kfs indicate a top to north sense of shear. Similar to the samples from the leading edge, this assemblage is stable at lower temperatures than the high-grade assemblages from the Red Wine Mountains massif.*

Plate 5. *Undeformed pegmatite dykes in Zone A mylonite. These dykes are commonly zoned with quartz- and muscovite-rich centres and margins composed of elongate euhedral feldspars up to several centimeters in length that have grown normal to the dyke contact. The dykes are clearly undeformed and unmetamorphosed, demonstrating that pegmatite emplacement is the youngest event in the Metchin River mylonite.*

Plate 6. *The dominant folds in the Zone B mylonite are symmetric and upright with limbs dipping as steeply as 70°. The limbs of these folds exhibit significant thinning and shearing, and thickening in fold hinges. Photograph of vertical face looking N-NE.*

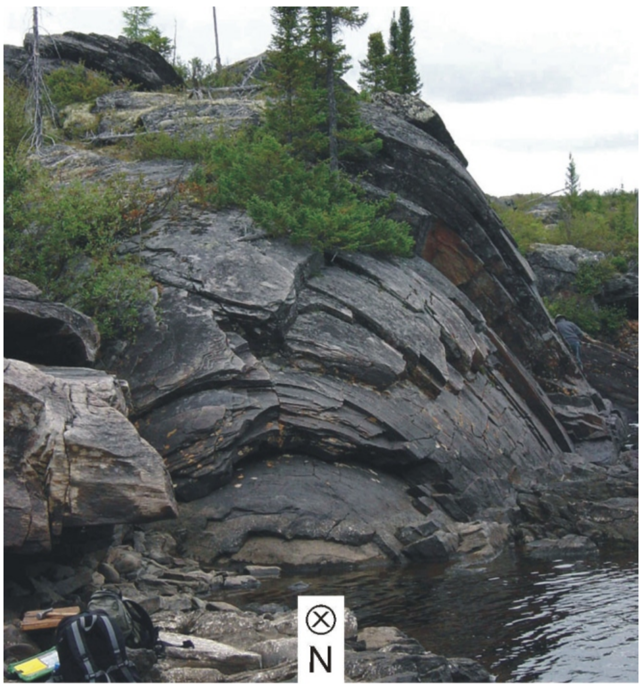

Plate 7. *The direction of folding in the Zone B mylonite is generally north–south but hinge lines dip variably to the north and south because of a later folding about a northeast-trending axis. The result is a distinctive interference fold pattern of domes and depressions.*

The boundary between the Zone A and Zone B mylonites appears to be gradational over a distance of a few tens of metres and extends roughly south, parallel to the East Metchin River until its confluence with the Metchin River. The earlier, upright folds of Zone B can be observed at one locality along the East Metchin River (484327 E, 5920610 N) to decrease in amplitude from west to east until only the gentle folds of Zone A mylonite remain. Immediately to the south of the mylonite, the leading edge of the RWMM, as a domain within the Wilson Lake terrane, is well defined by topography and magnetic signature. The contact of the Wilson Lake terrane with the ABT strikes in a northeast direction and appears to truncate the boundary between the Zones A and B mylonites (Figure 4).

Plate 8. *Pegmatites in the Zone B mylonite are parallel with the thinned and sheared limbs of the earlier folds, and in many places occupy the fold hinges.*

DISCUSSION

Field and petrologic studies demonstrate that rocks of the RWMM in the Wilson Lake terrane record a complex history of structural and metamorphic events prior to emplacement over the lower grade rocks also part of the Wilson Lake terrane. There seems little doubt that the peak metamorphism responsible for the sapphirine + orthopyroxene + sillimanite, and sapphirine + quartz assemblages in the paragneiss is of Labradorian age. Pervasive anatexis at this time likely involved the dehydration melting of titaniferous biotite and other phases to produce orthopyroxene, titanhematite, and melt. Recent experimental work (Koester *et al*., 2002) supports this model. Conditions of metamorphism and melting must have been at relatively high fO_2, slightly below the hematite/magnetite buffer. Reaction textures in some of these rocks from which the production of orthopyroxene + sillimanite + cordierite at lower temperature is inferred are consistent with a history of isobaric cooling as proposed by previous workers (Morse and Talley, 1971; Currie and Gittens, 1988). A late Labradorian age for the cooling is suggested by geochronological data on zoned monazites (Gross *et al.,* 2003). An extension of such a cooling path to still lower temperatures at roughly the same pressure (Figure 3) would account for the appearance of abundant kyanite in some rocks, especially the paragneiss at the leading edge of the Wilson Lake terrane. The sparse, coarser grained sillimanite in these rocks is likely relict, having formed initially during the production of cordierite + garnet at the expense of orthopyroxene + sillimanite + quartz (Figure 3). The assemblage cordierite + garnet + sillimanite subsequently cooled into the kyanite field, as inferred in Figure 3. Temperatures would have been in excess of 850º C, higher than those temperatures likely attained in these rocks during Grenvillian orogenesis. On that basis, the kyanite in the leading edge is likely Labradorian in age. The thin, kyanite-bearing pegmatitic seams may have been emplaced and recrystallized at this time, although a Grenvillian age for these seams cannot yet be excluded.

The Metchin River mylonite at the base of the RWMM also records a complex history. The mylonitic fabric in the upper Zone A has been subjected to at least one folding event about northeast-trending axes. These folds can be followed continuously into the lower Zone B mylonite where two fold episodes are apparent, and where sillimanite rather than kyanite is the predominant aluminosilicate. The earliest folds trend north–south, and undeformed pegmatite dykes are at a high angle to the ABT and may be truncated by it. There is no good evidence as yet to suggest that the kyanite-bearing paragneiss in the leading edge of the RWMM is related to the kyanite-bearing mylonite in Zone A. The spatial proximity of the paragneiss at the leading edge of the RWMM to the mylonite of Zone A is the only evidence at this time to suggest a common origin. Both kyanite and sillimanite have previously been described by Thomas (1993) in other parts of the Churchill Falls terrane that are unrelated to the mylonite. The proposed isobaric cooling of the RWMM is consistent with tectonically stable continental crust that has reached isostatic equilibrium. At some later time, the relatively cold RWMM was emplaced, under conditions of the kyanite stability field, over lower grade gneiss of the Wilson Lake terrane. It is unclear at this time that the Metchin River mylonite is the exhumed ductile shear zone along which the massif was emplaced. The presence of kyanite in the leading edge of the massif and in the mylonite would support this possibility, but the apparent truncation of fold structures and pegmatites in the mylonite by the massif along the ABT does not. An existing Grenvillian date on the pegmatites can only be considered a minimum age for the mylonite. A project is currently underway to date zoned, rotated monazite from the Metchin River mylonite. Dates from the rotated tails of these grains will provide a displacement age along the mylonite.

In the absence of additional age constraints, it remains possible that the Metchin River mylonite is older than Grenvillian and unrelated to the emplacement of the RWMM. It may be relevant that no such mylonite has been recognized along the southeast boundary of the RWMM, suggesting that the Metchin River mylonite is more closely related to the emplacement of the larger Wilson Lake terrane rather than to the emplacement of the massif.

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