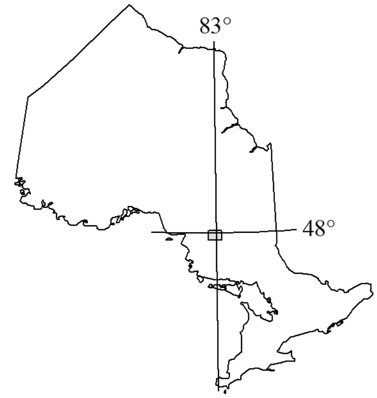
31. Identification of Partial Melting Relationships in the Southern Kapuskasing Structural Zone, Ontario



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INTRODUCTION

This report summarizes the first summer of field work investigating structural and metamorphic relationships within the southern Kapuskasing Structural Zone (KSZ), Chapleau–Foleyet area. This thematic project is part of the multi-year Metal Earth project led by the Mineral Exploration Research Centre (MERC) at Laurentian University, Sudbury.

The KSZ has been interpreted as an intracontinental portion of Archean lower continental crust, uplifted and thrust eastward upon the Abitibi Subprovince (Percival 1981). These high-grade metamorphic rocks have gained more interest in the last few years as a result of the major gold deposit discovered at the north end of Borden Lake, near the southern end of the KSZ (Murahwi, Gowans and San Martin 2012). This geological setting provides a great opportunity to 1) constrain the pressure–temperature (*P–T*) evolution of metamorphism and deformation processes recorded in the KSZ, a rare exposure of the lower continental crust, representing the roots of the Abitibi greenstone belt; 2) investigate the potential for partial melts to remobilize metals (e.g., gold, silver, copper, nickel and platinum group elements (PGEs)) from the middle-lower crust; and 3) understand the importance of partial melting in contributing metals to the upper crust.

Approximately 5 weeks were spent in the field conducting detailed bedrock mapping in the southern part of the KSZ. The objectives were to collect appropriate samples to gain insight into the tectonometamorphic evolution of the KSZ, and to identify partial melting characteristics by mapping along traverses guided by previously determined distribution of metamorphic grades.

REGIONAL GEOLOGY

The KSZ is a northeast-trending terrane of high-grade metamorphic rocks that cuts across the east-striking Archean Abitibi Subprovince to the east and the Wawa Subprovince to the west. The KSZ is fault bounded on both sides by crustal-scale shear zones interpreted by field relationships and reflection profiles: the Ivanhoe Lake fault on the east, and the Saganash Lake fault on the west (Percival and West 1994). The KSZ extends over 500 km in length and close to 50 km in width, and is characterized by strong positive gravity and aeromagnetic anomalies (Percival and West 1994). The KSZ can be divided into 3 blocks of distinct geological and geophysical character: from north to south, the Fraserdale–Moosonee, the Groundhog River and the Chapleau blocks (Percival and Card 1985).

Summary of Field Work and Other Activities, 2018,
Ontario Geological Survey, Open File Report 6350, p.31-1 to 31-7.

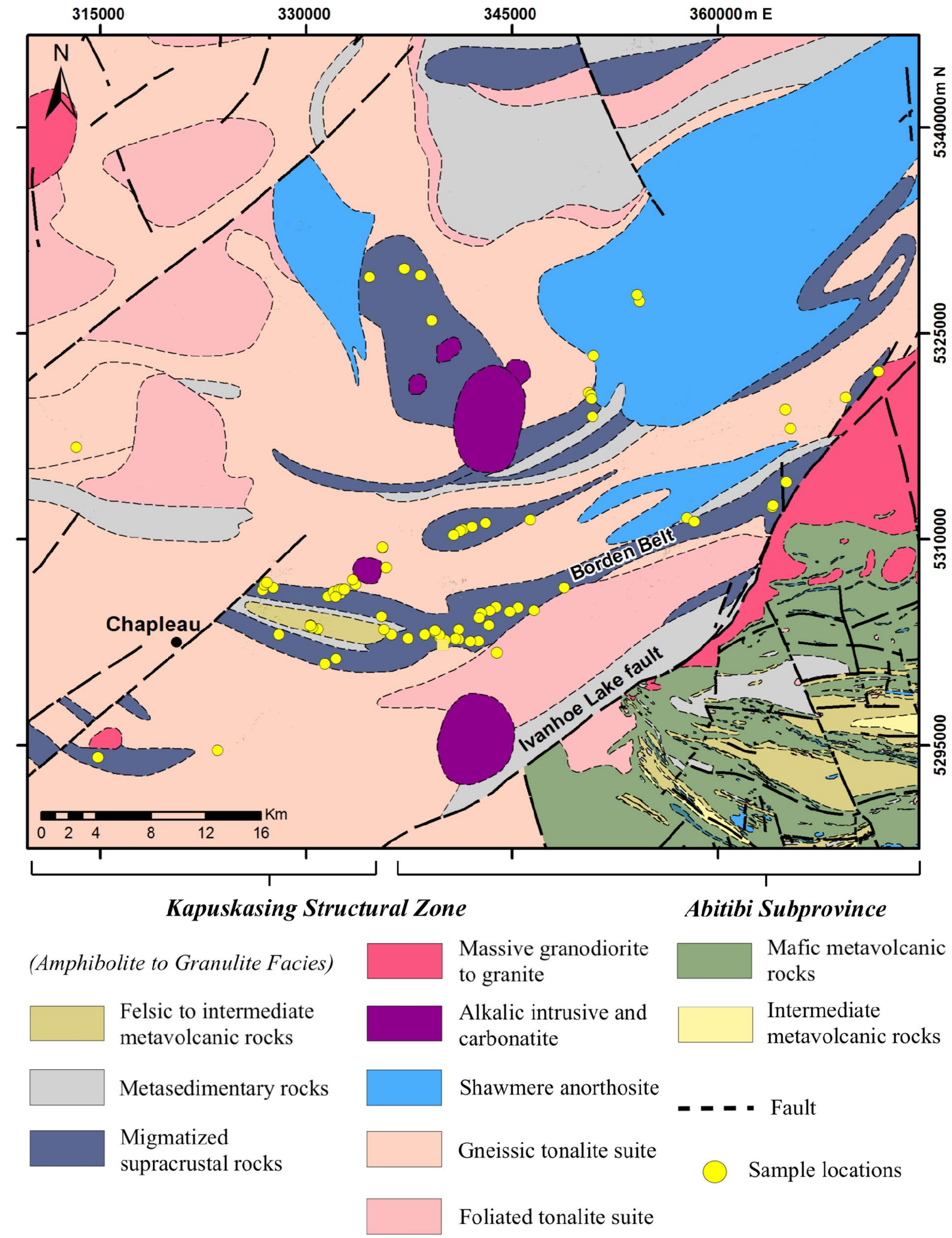

Figure 31.1. Geology of the southern Kapuskasing Structural Zone (the area of study) and the contact with the Abitibi Subprovince (*modified from* Ontario Geological Survey 2011). The yellow circles correspond to locations of samples collected. "Borden Belt" on the map is the Borden Lake greenstone belt. Universal Transverse Mercator (UTM) co-ordinates are provided using North American Datum 1983 (NAD83) in Zone 17.

The Fraserdale–Moosonee block consists mainly of metasedimentary granulites, tonalite and rare mafic gneiss, whereas the Groundhog River block contains a heterogeneous sequence of tonalitic orthogneiss, mafic gneiss and rare paragneiss (Percival and McGrath 1986). The Chapleau block is dominantly orthogneiss, minor paragneiss and mafic gneiss (Figure 31.1). The metamorphic grade of rocks in the Chapleau block range from upper amphibolite to granulite facies, with the degree of migmatization increasing to the north-northwest (Percival and McGrath 1986). The presence of the large Shawmere anorthosite complex within the Chapleau block is consistent with exhumation of the block to expose the deep crust.

The Borden Lake greenstone belt (BLGB) of volcano-sedimentary supracrustal and intrusive rocks hosted within the Chapleau block is recognized as a different geological package from the rest of the KSZ (Percival 1981; Moser 1993). The BLGB, which is host to the recently discovered gold deposit at the north end of Borden Lake, can be subdivided into 3 different subunits (Duguet and Szumylo 2016). The southern part of the belt is the lowermost tectonostratigraphic subunit, predominantly composed of mafic to intermediate metavolcanic rocks. The intermediate subunit hosts the Borden Lake gold deposit and is located in the core of the BLGB. This subunit is represented by a thick package of felsic metavolcanic rocks, metasedimentary rocks and felsic intrusive rocks (Duguet and Szumylo 2016).

The upper subunit consists of Timiskaming-type metaconglomerates. Estimates of *P–T* on a migmatized mafic gneiss with a mineral assemblage of garnet + diopside + plagioclase + quartz yielded 685 to 735°C and 9 kilobars (Hartel and Pattison 1996). Pressure and temperatures associated with partial melting may have approached 850°C and 11 kilobars, based on experimental studies of dehydration melting of amphibolite in the interpreted mineral reaction (Hartel and Pattison 1996). Zircon U/Pb geochronology results from a mafic granulite collected along Highway 101 at the northern part of the Chapleau block yielded an age of 3191±14 Ma (Benn and Kamber 2009), which records a metamorphic event that occurred 430 m.y. before the earliest documented mafic magmatism in the Abitibi Subprovince. This mafic granulite sample, along with a metatonalite collected in the same area, yielded U/Pb zircon ages ranging between 2869±15 and 2784±14 Ma, and were interpreted to also record a metamorphic event earlier than the Abitibi Subprovince (Benn and Kamber 2009). However, the above-mentioned samples also contain younger zircons; the mafic granulite also yielded a concordant U/Pb zircon age of 2698±16 Ma, which records the age of metamorphic crystallization (Benn and Kamber 2009).

Zircon U/Pb geochronology results from leucocratic material in migmatitic granulites yielded an age of *circa* 2667 Ma, which is interpreted as the age of metamorphic zircon growth (Krogh and Moser 1994), and crystallization ages of 2925±35 Ma and 2725±5 Ma for zircons obtained from migmatitic tonalite gneisses in the southern part of the Chapleau block (Moser 1993). Detrital zircon U/Pb geochronology results from metaconglomerates in the BLGB indicate a depositional age of *circa* 2.66 to 2.69 Ga (Krogh 1993).

FIELD WORK AND OBSERVATIONS

To constrain the tectonometamorphic evolution of the southern area of the KSZ, representative samples of mafic and felsic rocks with optimal mineral assemblages for phase equilibria and geochronology work were collected from the various geological units of interest, as well as samples of leucosomes, melanosomes and mesosomes from rocks that experienced partial melting. Although a large area was covered, the majority of outcrops observed are located in the BLGB and are of mafic composition.

Mafic rocks in the BLGB consist of amphibole + plagioclase + clinopyroxene ± orthopyroxene ± quartz ± garnet ± accessory minerals, based on field observations. Mafic rocks in the north-northeastern part of the BLGB include minor orthopyroxene in the mineral assemblage compared to the predominantly clinopyroxene-bearing assemblages in the southern part of the BLGB. This difference in mineral assemblages suggests that rocks in the northern part of the BLGB experienced granulite-facies metamorphic conditions, whereas rocks in the southern part of the BLGB only experienced upper amphibolite-facies conditions, characterized by an amphibole + clinopyroxene + plagioclase assemblage. However, the upper amphibolite-facies assemblage might represent a retrograde overprint, as previously suggested (Percival 1981; Percival and Card 1985; Moser 1993; Duguet and Szumylo 2016). The transition between upper amphibolite and granulite facies is difficult to determine from field observations alone because the amphibolite + clinopyroxene + plagioclase assemblage can be stable at the lower granulite facies in calcium-rich bulk-rock compositions (>10 weight %). Further thermobarometry and geochemical analysis on the samples collected is required in order to establish the transitions in metamorphic grade. Phase equilibria modelling and geochemistry will constrain the metamorphic processes preserved in the rocks (partial melting and melt extraction) and the temperature–pressure conditions reached during peak metamorphism.

The mafic rocks of the BLGB show a range of garnet abundance. Locally, outcrops show abundant subhedral and evenly distributed garnets in the matrix of the rock, whereas other outcrops lack garnet crystals in the matrix. Initial field observations suggest a change from amphibolite to garnet-bearing amphibolite moving from the BLGB margin inward, but further mapping is required to establish this relationship. In this same mafic rock package, the grade of migmatization (volume of melt produced) appears to increase to the north-northeast, although partial melting is not restricted to the northern area of the BLGB and Chapleau block (Photo 31.1A). Classifying these rocks in the field relies on an accurate estimate of melanosome and leucosome proportions and features, which can be difficult because of poor exposure. Regardless of the presence of garnet in the matrix of mafic rocks, garnet is commonly found within or along the margins of the leucosome and, therefore, is interpreted to have formed during melting (i.e., peritectic). Locally, these peritectic garnets are surrounded only by the melanosome, suggesting the migration of a former leucosome (i.e., melt segregation). Further petrographic work is necessary to understand this relationship. Several outcrops of mafic rocks have melanosomes that are generally organized in relatively continuous boudinaged layers with schollen textures.

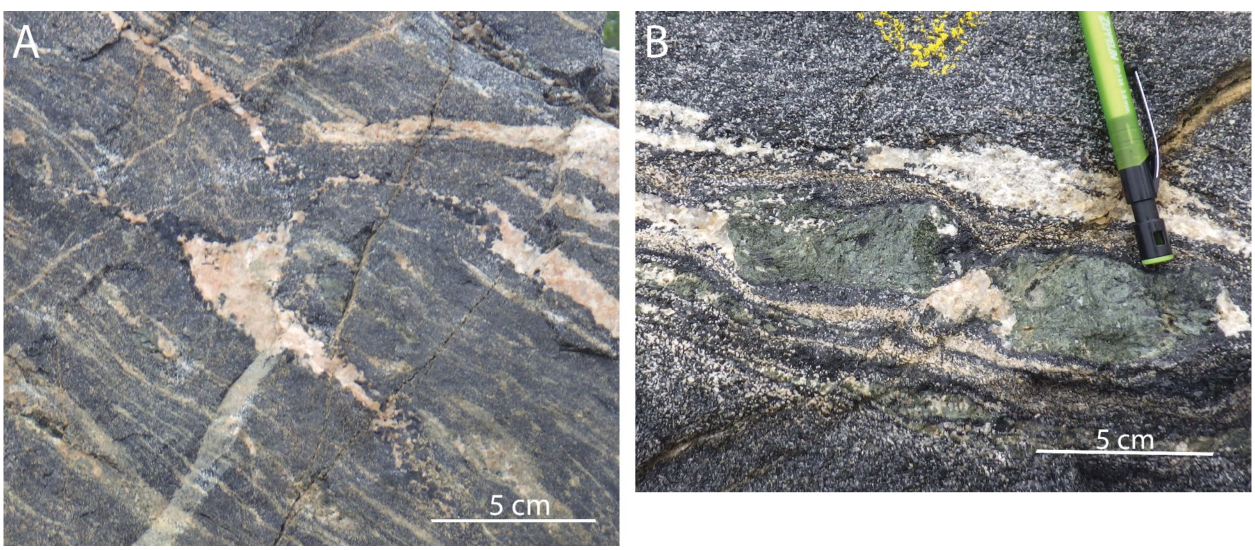

Photo 31.1. Photos illustrating some of the rock characteristics observed in the field. **A)** Mafic rock with *in situ* melt as evidenced by a leucosome (plagioclase + quartz) surrounded by a potentially orthopyroxene-bearing melanosome (UTM 321234E 5297355N). **B)** Clinopyroxene core surrounded by amphibole; this is interpreted as a back reaction of the orthopyroxene to amphibole (UTM 341204E 5310595N). All UTM co-ordinates provided using NAD83 in Zone 17.

The features observed along the BLGB can be related to some of the characteristics seen in the mafic rocks of the Chapleau block. The mafic rocks to the north-northeast have orthopyroxene in the mineral assemblages, compared to the orthopyroxene-absent mineral assemblages to the south. However, 1 outcrop (UTM 321234E 5297355N) to the south of Chapleau Township appears to have orthopyroxene in the melanosome mineral assemblage, suggesting granulite-facies conditions were reached (*see* Photo 31.1A). A noteworthy feature was observed in many of the mafic gneiss outcrops, where a core of clinopyroxene was surrounded by a rim of amphibole (Photo 31.1B). This feature is interpreted to represent a granulite-facies assemblage retrogressed to upper amphibolite facies. In some outcrops, a network of leucosomes was observed in the mafic rocks: the leucosomes are approximately 4 cm wide and continuous along the outcrops. This leucosome material locally hosts garnet and amphibole. There was no residuum material along the borders of these networks. Further geochemical analysis is needed to understand if these networks represent *in situ* anatexis or if the leucosomes represent externally derived melt infiltrating the mafic host.

Although much of the field work focussed on mafic rocks, some observations were made in the felsic paragneisses. These rocks typically show a mineral assemblage of amphibole + plagioclase + quartz ± garnet. Some outcrops contain mafic xenoliths with a reaction rim of biotite and, in some cases, these mafic xenoliths are strongly deformed. Another feature observed in some outcrops is the presence of more leucocratic layers, generally with a simple mineral assemblage of plagioclase + quartz ± coarser biotite ± coarser muscovite that could potentially represent leucosome. These layers are mostly concordant with the foliation and parallel to pegmatitic dikes. The occurrence of garnet in these rocks is minor, however, samples of felsic gneiss with garnet were collected in order to help constrain the tectonothermal evolution by using garnet-biotite or other mineral assemblages to allow phase equilibria modelling. This modelling will help constrain the pressure–temperature evolution of the felsic rocks sampled.

Sulphides were observed in the mafic gneisses along the BLGB and in the Chapleau block. The occurrence of chalcopyrite, pyrrhotite and pyrite was observed in minor proportions, disseminated in the matrix of the rock. Magnetite is locally present, with coarser magnetite occurring in pegmatite dikes.

Structural measurements were recorded and compiled in order to relate the petrographic and geochemical work to the deformation history. In general, the rocks observed in the KSZ and BLGB are consistently and strongly deformed. The dominant fabric is characterized by a shallowly northeast-dipping foliation. This dominant foliation varies along boudins and isoclinal folds at outcrop scale. The boudins present 2 different features within the mafic and felsic rocks: some are symmetric boudins with boudins necks of leucocratic material (plagioclase + quartz), and others are asymmetric boudins that have a sigmoidal shape, indicating a sinistral shear sense.

FUTURE WORK

Samples were collected from the various geological units of the southern KSZ (*see* Figure 31.1) for detailed petrographic, petrologic and geochemical analyses utilizing scanning electron microscope (SEM) imaging, energy-dispersive X-ray spectrometry (EDS) mapping, microprobe analysis and laser ablation inductively coupled plasma mass spectrometry (LA-ICP–MS) analysis. Subsequent phase equilibria modelling and geochronology will help constrain the *P–T* conditions of metamorphism and the tectonometamorphic history of the area. Geochronology will include U/Pb and trace element analyses of zircon and monazite from characteristic metamorphic features (e.g., leucosome, restite and pegmatite) found in representative lithological packages from each unit.

Analyses comparing mafic and felsic rocks that have undergone partial melting and those that have undergone melting extractions, along with their trace metal chemistry, will be used to understand the mobilization of metals. Mesosome, melanosome and leucosome components will be analyzed separately, using high-precision geochemistry.

RELEVANCE

The KSZ represents a portion of the lower Archean continental crust that consists of high-grade metamorphic rocks, uplifted to the structural level of the surrounding gold-bearing greenstone belts. Some KSZ packages lie within the BLGB and host a major gold deposit found within felsic rocks of the intermediate subunit. Despite this gold deposit occurring only in a single geographic location, understanding the relationship of partial melting and remobilization of metals from the middle-lower crust to the upper crust is important for understanding the processes associated with the formation of the Borden Lake mineral deposit, as well as gold deposits such as those in the nearby greenstone belts. In order to obtain a comprehensive understanding of these processes, it is necessary to constrain the tectonothermal evolution history of the area of study by doing detailed metamorphic petrology work.

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