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ORTHOMAGMATIC Fe–Ti–V OXIDE MINERALIZATION HOSTED IN PALEOPROTEROZOIC ANORTHOSITE IN THE CAPE CARIBOU RIVER ALLOCHTHON, GRENVILLE PROVINCE, SOUTHEAST LABRADOR: PRELIMINARY RESULTS

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ABSTRACT

Proterozoic massif-type anorthosites and related gabbronoritic rocks form large bodies through much of Labrador, and are known to contain orthomagmatic Fe+Ti±V±Cr±P oxide mineralization. Although several of these zones of mineralization were encountered throughout Labrador during the mineral exploration boom following the Voisey's Bay discovery in 1994, very few were investigated in detail. This paper presents a summary of fieldwork and preliminary petrographic results of an ongoing study by the senior author investigating the characteristics of Fe–Ti–V oxide mineralization in the Cape Caribou River allochthon.

The Cape Caribou River allochthon is a lobate ca. *1625 Ma Paleoproterozoic massif-type anorthosite–mangerite–charnockite–granite (AMCG) suite located within the Grenville Province of southeastern Labrador. The uppermost unit in the Cape Caribou River allochthon is the North West River anorthosite, a heterogenous unit containing rocks ranging from anorthosite* sensu stricto *(>90% plagioclase) to gabbronoritic rocks. Within this unit, irregular blebs of large (<1 cm to m scale), primary pyroxene (clinopyroxene > orthopyroxene) are abundant and are ubiquitously rimmed by ferromagnesian amphiboles, calcic amphiboles, biotite, garnet and hornblende. Four main modes of Fe–Ti–V mineralized occurrences are present in the anorthositic rocks, including: 1) pods of semi-massive to massive oxide (apatite-rich and apatite-poor); 2) oxide veins (straight or irregular contacts with the host rocks); 3) disseminated oxide (oxide mineralization occurring on its own or associated with pyroxene); and 4) alternating bands of oxides and anorthositic rocks. The Fe–Ti–V oxide mineralization consists of both the spinel series (ulvospinel–magnetite solid solution) and the trigonal series (ilmenite–hematite solid solution), and is often associated with pyrrhotite, chalcopyrite and pyrite. In addition, magmatic sulphide mineralization is locally found and is composed of pyrite, chalcopyrite, pyrrhotite and minor pentlandite. Whole-rock lithogeochemical data of a sulphide vein sample showed combined metal grades of <1% Ni and Cu.*

INTRODUCTION

Numerous occurrences of orthomagmatic Fe–Ti–V oxide mineralization (Figure 1) were discovered in various geological settings throughout Labrador since 1994, most being discovered during the exploration boom, following the Voisey's Bay discovery (Hinchey *et al.,* 1999; MacDonald, 1999; Kerr *et al.,* 2001, 2013; Dyke *et al.,* 2004). Despite these discoveries, few of the mineral occurrences have had follow-up exploration or study because past exploration efforts were largely focussed on looking for magmatic nickel sulphide deposits (Kerr *et al.,* 2013, and references therein). In Labrador, oxide mineralization is recognized within four main types of Proterozoic plutonic rocks: 1) anorthosite, 2) gabbro–troctolite, 3) pyroxenite, and 4) ferrodiorite (*e.g.*, Kerr and Ryan, 2000; Kerr *et al.,* 2013, and reference therein).

Iron, titanium and vanadium are vital commodities for use in steel and other alloys, and vanadium is also becoming increasingly important in the renewable energy storage industry (*e.g.*, Fabjan *et al.,* 2001; Schreiber *et al.,* 2012). For these reasons, the economic potential of known and undeveloped Fe–Ti–V oxide occurrences is of significant interest (*e.g.*, Kerr *et al.,* 2013). In a recent review of vanadium potential in the Province, Kerr *et al.* (2013) provided a

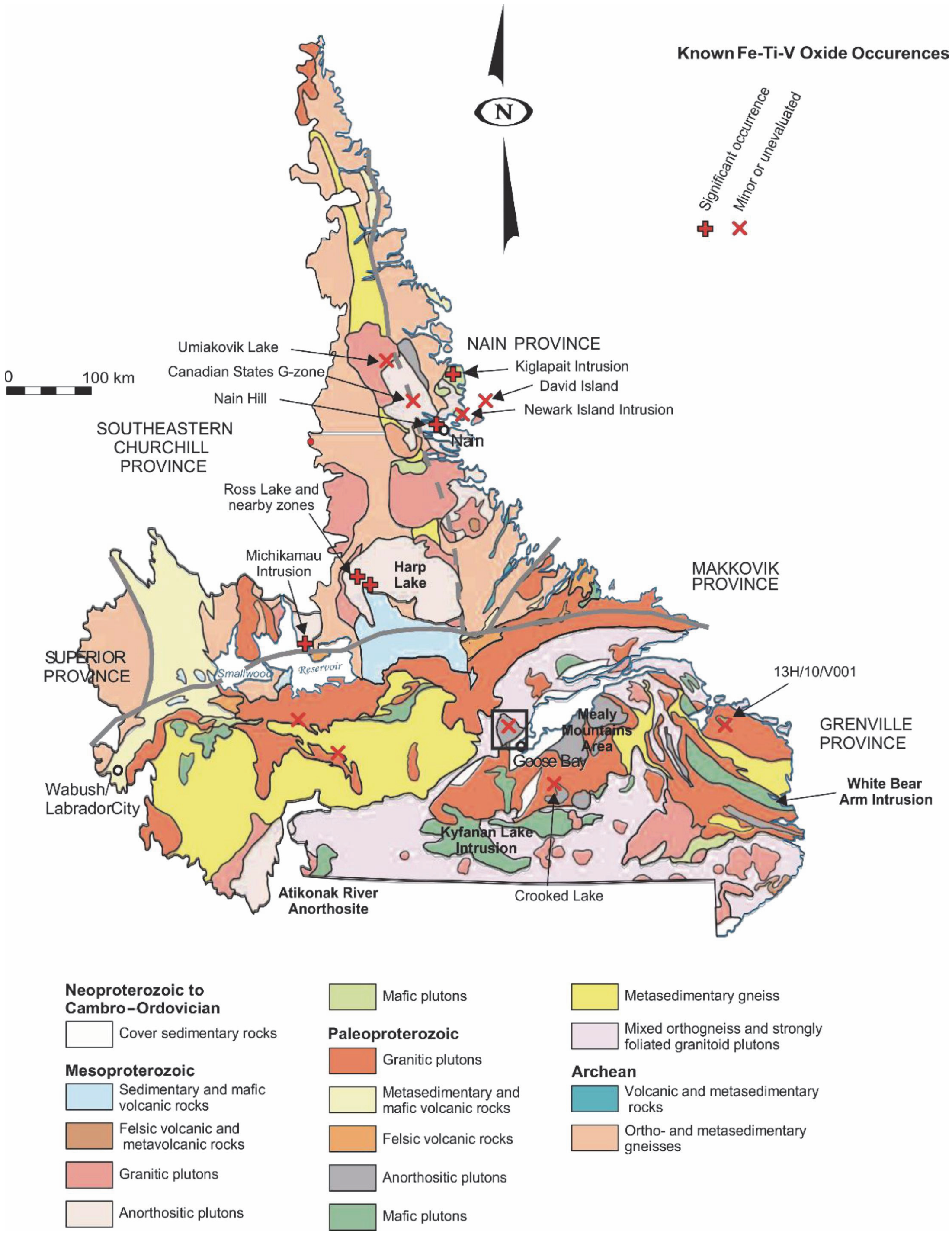

Figure 1. *Simplified geological map of Labrador showing locations of known orthomagmatic Fe–Ti–V oxide mineralization and the outline of the study area in black box (modified from Kerr* et al.*, 2013).*

summary of known oxide occurrences, and highlighted the need for further research in several areas in Labrador, including the Cape Caribou River allochthon (CCRA) (Figure 2). In light of this need, a research project was initiated to evaluate Fe–Ti–V oxide mineralization hosted by Proterozoic plutonic rocks in Labrador (Figure 1). This research is being conducted at the Labrador Institute of Memorial University of Newfoundland, in partnership with the Mineral Deposits Section of the Geological Survey of Newfoundland and Labrador, and the Department of Earth Sciences, Memorial University of Newfoundland.

Part of this research project is investigating Fe–Ti–V oxide mineralization in the CCRA, and is the basis of a Master's thesis by the senior author. The objectives of the current research are to systematically determine: 1) the mineralogical associations and textural relationships within, and between, Fe–Ti–V oxide mineralization and its anorthositic host rocks; 2) chemical variations in different oxide minerals, focusing especially on vanadium and titanium contents; 3) whole-rock lithogeochemical variations, including major, trace and rare-earth elements; and 4) Sr, Nd and Pb isotopic compositions in the host anorthositic rocks. This information will assist in deciphering the major factors and processes involved in the formation of the Fe–Ti–V oxide mineralization, and will aid in future exploration. It will also provide insight into the genetic relationship between the host rocks and mineralization, and the effect of Fe–Ti–V oxide mineral compositions and exsolution textures on the amenability to mineral processing.

The CCRA was previously mapped at 1:125 000 scale (Ryan *et al.*, 1982; Wardle and Ash, 1984, 1986), and regional aeromagnetic studies show a highly anomalous magnetic zone (4 by 17 km) within the western portion of the CCRA (Figures 2 and 3). This project focuses primarily on a 3.5 by 3.5 km area at the northern end of the magnetic anomaly, which encompasses a block of claims (the Cape Caribou property) staked by prospectors T. Benoit and C. Coady. During the summers of 2013 and 2014, fieldwork was conducted in the CCRA area and outcrop samples were collected. This paper provides a summary of the fieldwork and the preliminary results obtained from petrographic examinations of the main mineralized occurrences and anorthositic host rocks observed in the Cape Caribou River allochthon.

GEOLOGICAL SETTING

REGIONAL CONTEXT

The study area is located in southeast Labrador, within the Grenville Province (Figure 1) and is composed of late Paleoproterozoic and Mesoproterozoic rocks that formed during four orogenic events: the 1860–1790 Ma Makkovik orogeny, 1710–1600 Ma Labradorian orogeny, 1520–1460 Ma Pinwarian orogeny, and 1085–985 Ma Grenvillian orogeny (Gower *et al.,* 1992, 2008; Gower and Krogh, 2002; Tollo *et al.,* 2004). The first three of these were active-margin accretionary events that were responsible for adding new juvenile crust, and deforming and metamorphosing the existing Paleoproterozoic orthogneissic and paragneissic crust (Krauss and Rivers, 2004). The Grenvillian orogeny, in contrast, represents an episode of continent–continent collision that terminated active Proterozoic accretionary tectonism and caused the most intense metamorphism in the region (Krauss and Rivers, 2004). In addition, the region experienced three main pulses of anorthosite–mangerite–charnockite–granite (AMCG) plutonism during the period *ca.* 1650–1000 Ma (Davidson, 2008).

The Grenville Province is well known for its extensive AMCG suites that host orthomagmatic Fe–Ti (± V ± P ± Ni ± Cr ± PGE) deposits. Similar Fe–Ti deposits are found in AMCG suites globally (*e.g.*, Gower *et al.,* 1995; Dymek and Owens, 2001; Hébert *et al.,* 2005; Gauthier and Chartrand, 2005; Morisset *et al.,* 2010; Charlier *et al.,* 2010; Kerr *et al.,* 2013), and the Grenville Province is host to the world-class Lac Tio Fe–Ti oxide deposit in Québec, which contains over 125 Mt of hemo-ilmenite ore averaging 32% TiO_2 and 36% FeO (Hammond, 1952; Charlier *et al.,* 2010). Additionally, vanadium, chromium and phosphate are reported as by-product commodities for a number of AMCG-hosted orthomagmatic oxide deposits in the Grenville Province (Perreault and Hébert, 2001; Hébert *et al.,* 2005; Corriveau *et al.,* 2007). The origin of the parental magmas of AMCG suites and massif-type anorthosites is still debated, as are the key controlling factors of accumulation and preservation of oxides within the anorthositic rocks (*e.g.*, Morisset *et al.,* 2010; Charlier *et al.,* 2010).

LOCAL GEOLOGY

The CCRA is a thick, lobate Grenvillian thrust slab (Figure 2: Wardle *et al.,* 1990; Philippe *et al.,* 1993; Krauss and Rivers, 2004). It was formed during post-collisional events of the Labradorian orogeny, which was a period characterized by significant mafic, felsic and AMCG plutonism. The CCRA represents a transported segment of the much larger Mealy Mountains intrusive suite (MMIS). Subsequent to its emplacement, the MMIS was subjected to several tectonic events, primarily being transported northward across the foreland during the Grenville orogeny, and further northwestward during the Neoproterozoic rifting events around the Grenvillian Lake Melville rift system. These two events divided the MMIS into the Mealy Mountain terrane (MMT) and the CCRA (Scharer *et al.,* 1986; Wardle *et al.,* 1990; Philippe *et al.,* 1993; Gower, 1996; Gower and Krogh, 2002). The U–Pb zircon geochronology from the basal gneisses of the CCRA shows evidence of the effects of both the Grenvillian and the Labradorian orogenies (Bussy *et al.,* 1995).

The CCRA is bound at its base by mylonitic faults. It is mainly composed of Paleoproterozoic AMCG rocks, specifically dioritic to granodioritic orthogneiss, amphibolite, mafic granulite, and minor metasedimentary gneiss (Ryan *et al.,* 1982; Wardle and Ash, 1984, 1986). The North West River anorthosite is a *ca.* 500 km^2 pluton located at the top of the CCRA (Figure 2), which has been dated at *ca.* 1625

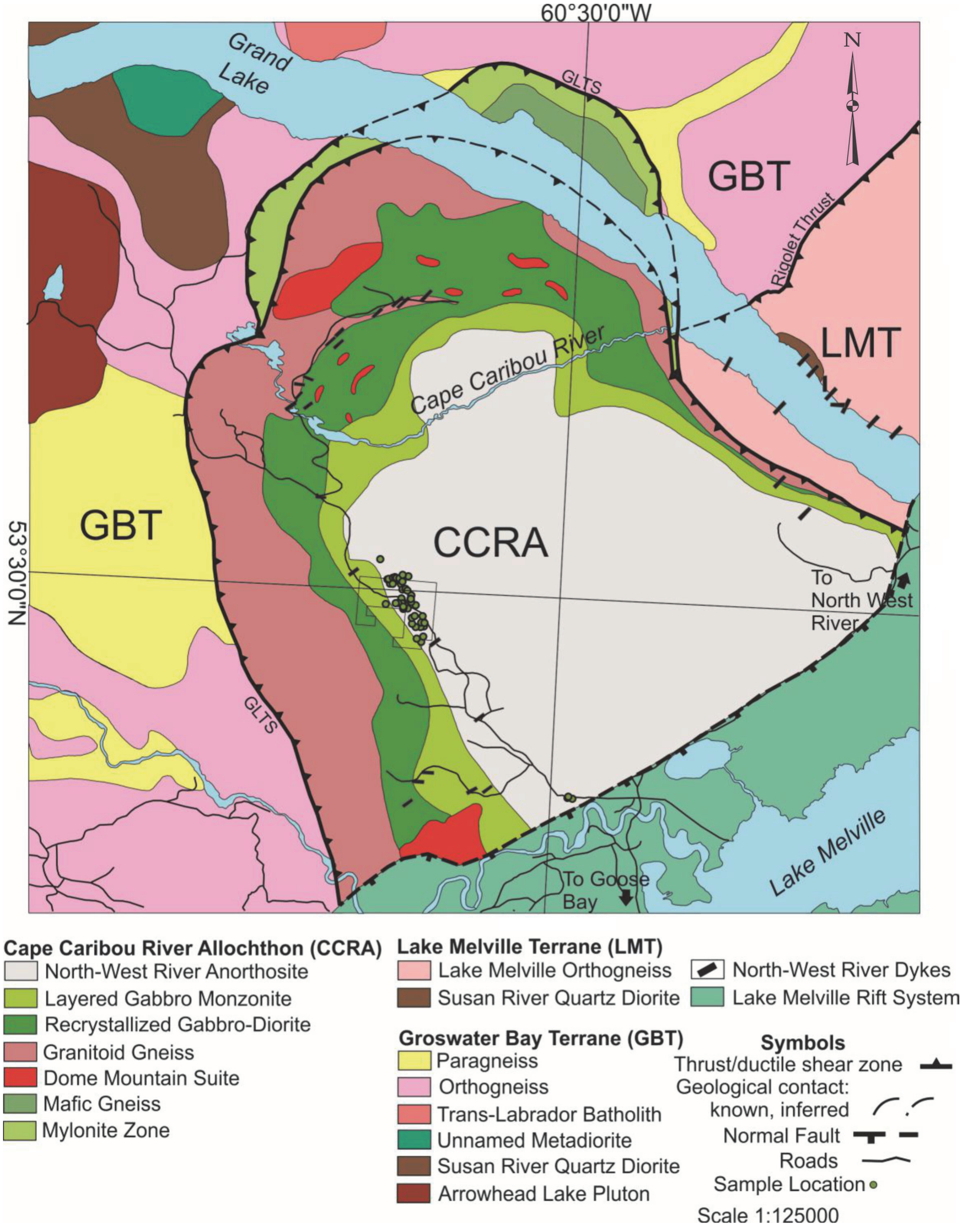

Figure 2. *Geological map of the Cape Caribou River allochthon showing the North West River anorthosite in the centre and surrounding rock units. The Cape Caribou property is outlined in black solid line (modified from Krauss and Rivers, 2004).*

Ma (Bussy *et al.,* 1995; Krauss and Rivers, 2004). It was undeformed during northwest-directed thrusting of the allochthon (Krauss and Rivers, 2004).

Although the CCRA is a favourable target area for hosting orthomagmatic Fe–Ti–V oxide mineralization, it has yet to be widely explored with only sparse prospecting and exploration activities following the Voisey's Bay discovery (Kerr *et al.,* 2013). Examples of semi-massive to massive oxide mineralization were first identified in anorthositic outcrops within the CCRA by prospectors T. Benoit and C. Coady. Subsequent whole-rock lithogeochemical analyses indicate up to 81.78% Fe_2O_3 (or 57.2% Fe), 14.14% TiO_2, 3500 ppm V (or 0.62% V_2O_5), and variable enrichments in Cr, Cu and P_2O_5 (up to 4410 ppm, 1150 ppm and 5.21%, respectively) (A. Valvasori, unpublished data, 2014).

SUMMARY OF FIELDWORK AND PRELIMINARY PETROGRAPHIC STUDIES

The study area is located between latitudes 53.50ºN and 53.37ºN and longitudes 60.67ºW and 60.52ºW, approximately 30 km northwest of Happy Valley-Goose Bay (Figure 2). Field access is *via* Grand Lake Road, which is a well-maintained gravel forestry road that branches from the paved Route 520, which extends from Happy Valley-Goose Bay to North West River. The field area is forested with jack pine, spruce and fir, with several burnt-over zones. Although bedrock outcrops are abundant in the area, recovering fresh samples is difficult because of surface weathering and typically smooth, rounded outcrop surfaces. There is an 80-m-elevation change in the field area, marked by a ridge to the west and low-lying muskeg to the east.

Most of the outcrops sampled are located within 2 km of the Grand Lake Road, and occur in the large aeromagnetic anomaly in Figure 3. Samples were also collected from abandoned blast pits and quarries near the intersection of Grand Lake Road and North West River Road, falling within an area characterized by medium magnetic intensity values on the regional aeromagnetic map (Figure 3).

Samples taken for this study consist of both mineralized and barren rocks near the contact between the North West River anorthosite (NWRA) and the underlying layered gabbro monzonite unit (Figure 2). Mineralized samples show a variety of oxide mineral assemblages and abundances, and range from massive oxide-rich rocks (>90 vol% oxides) through to semi-massive oxides (25–90 vol% oxides), to disseminated (5–25 vol% oxides) oxide-bearing anorthositic rocks. Barren samples contain <5% oxide mineralization.

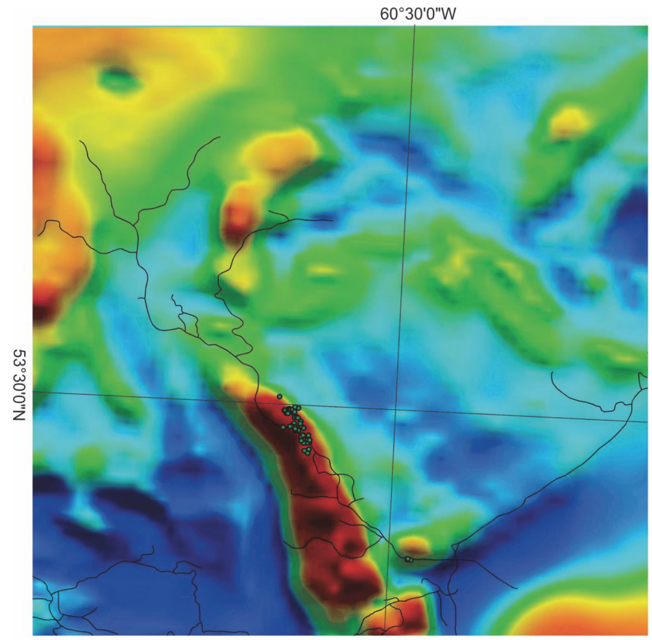

Figure 3. *Regional aeromagnetic map of the Cape Caribou River allochthon showing plotted sample locations (from the NL Geoscience Atlas). Note the relationship between the red aeromagnetic high and the contact between the North West River anorthosite and layered monzonite. Roads are indicated by black lines.*

GEOLOGY OF THE STUDY AREA

The study area is underlain mainly by the NWRA, a heterogeneous unit primarily composed of anorthosite *sensu stricto* to gabbronoritic rocks (Plate 1A). These rocks are heterogranular and composed of medium- to coarse-grained plagioclase crystals that range from <1 cm to 25 cm in length. Plagioclase crystals range in colour from white, to light grey, and in rare cases mauve to lilac (Plate 1A). Although recrystallization of plagioclase is uncommon, sericite alteration is weak to moderate in most samples, and occurs in higher concentrations near oxide-rich pods. Labradorescence is locally found associated with plagioclase in the study area, and where present is in areas of apparent higher metamorphic grade.

Primary ferromagnesian minerals in the anorthosite and gabbronoritic rocks include pyroxene (clinopyroxene > orthopyroxene), amphiboles and rare olivine. In hand specimens, pyroxene crystals are generally tan to buff, whereas amphiboles are dark green to black (Plate 1B–D). These ferromagnesian minerals, which occur in single grains or clusters of grains, are complex and blebby, and vary in size proportionally to the adjacent plagioclase grains (commonly

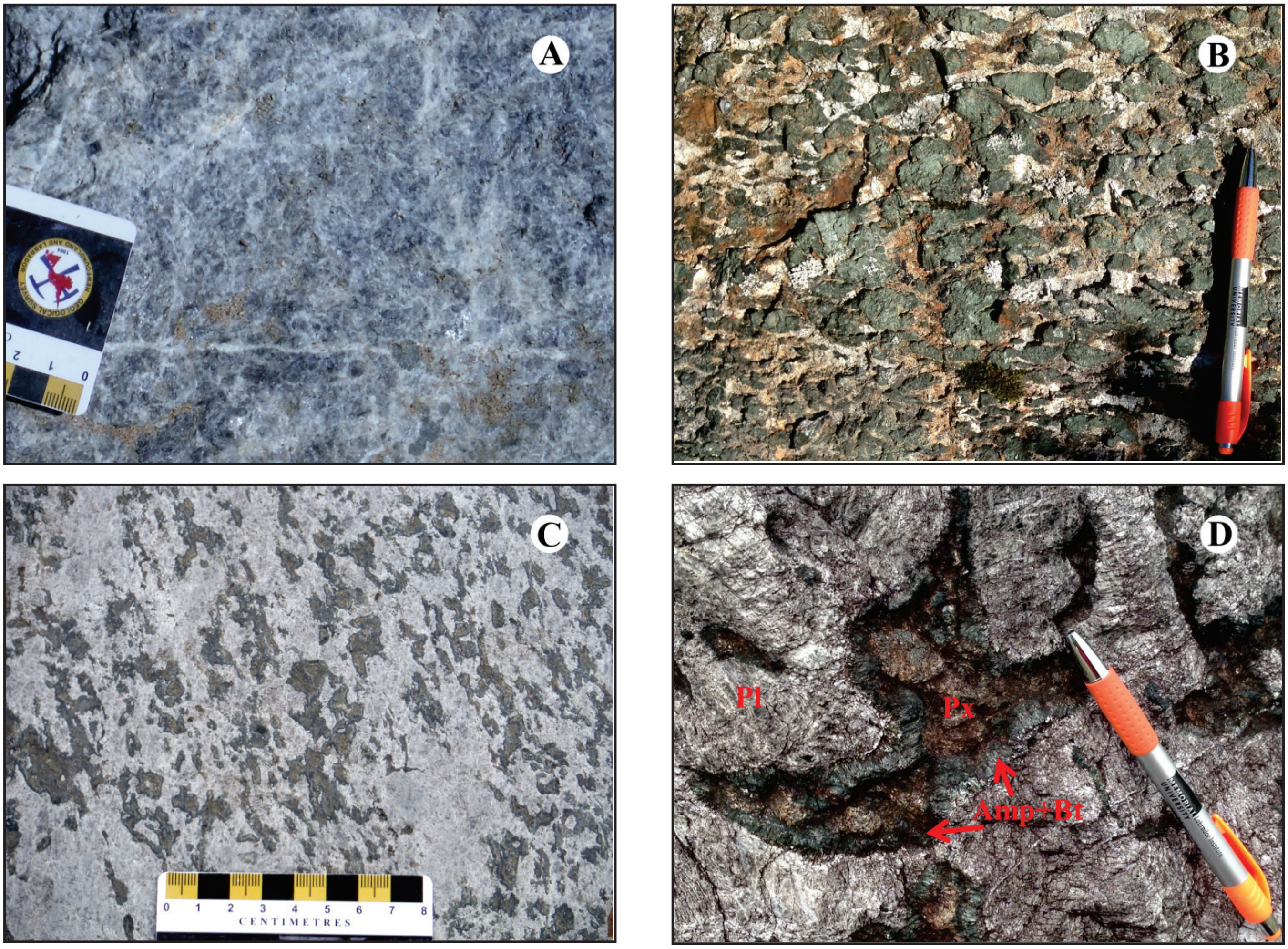

Plate 1. *Field photographs of unmineralized host rocks, showing the range in mineralogical compositions and relationships. A) Outcrop of coarse-grained anorthosite (sensu stricto); B) Outcrop of gabbronorite, showing lens-shaped grains of pyroxene and amphibole; the pyroxene is dominantly clinopyroxene; C) Outcrop of anorthosite, exhibiting irregular-shaped blebs of pyroxene, amphibole and biotite. D) A large bleb of coarse-grained pyroxene, rimmed by a green band of amphibole and minor biotite; and E) A xenolith of dark-grey fine-grained gabbro in the gabbronorite. Abbreviations: Px–pyroxene; Pl–plagioclase; Amp–amphibole; Bt–biotite.*

between 5 mm and 20 cm). The rocks have a wide range in modal abundance of ferromagnesian minerals (from 0–70%). Oxide mineralization is commonly associated with the ferromagnesian phases (Plate 1B–D).

Polymineralic coronas, composed of calcic amphibole, ferromagnesian amphibole, hornblende, biotite, garnet, and rarely clinopyroxene surround pyroxenes, olivine, oxides and sulphide minerals (Plates 1D and 2A). In rare cases,

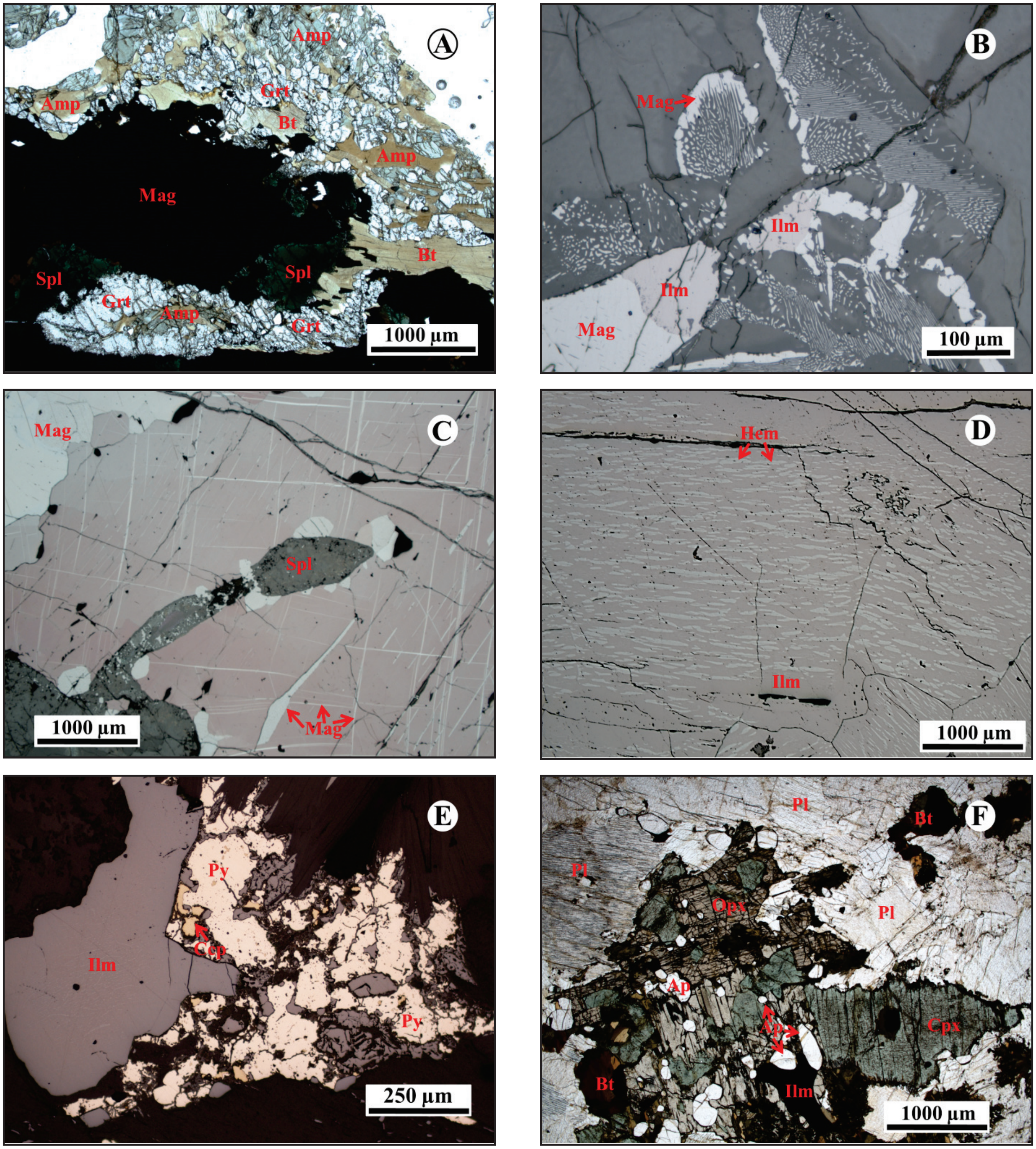

Plate 2. *Representative photomicrographs, displaying typical associations of oxide minerals and exsolution textures. A) Magnetite and aluminous spinel with a hydrous rim of two types of amphibole (likely hornblende and actinolite), biotite and garnet (plane-polarized light); B) Intergrowth of magnetite and ilmenite (droplet in the bottom left-hand corner) with symplectic magnetite-silicate (dark grey) intergrowths (reflected light); C) Ilmenite grain containing fine magnetite lamellae and inclusions of aluminous spinel (reflected light); D) Densely packed rod-like exsolution lamellae of hematite in ilmenite grains (reflected light); E) Ilmenite associated with sulphide minerals, pyrite and chalcopyrite (reflected light); and F) Cluster of clinopyroxene, orthopyroxene, apatite and biotite, surrounded by plagioclase in a weakly mineralized host rock (plane-polarized light). Abbreviations: Amp–amphibole; Grt–garnet; Bt–Biotite; Spl–Spinel; Mag–magnetite; Ilm–ilmenite; Hem–hematite; Ccp–clinopyroxene; Py–pyrite; Opx–orthopyroxene; Cpx–clinopyroxene; Ap–apatite; Pl–plagioclase.*

symplectic intergrowths of oxide and silicate phases are present (Plate 2B). Sometimes, goethitic alteration and other weathering minerals are present adjacent to massive or semi-massive oxides, along cracks in plagioclase and associated with aluminous spinel inclusions in semi-massive oxide minerals.

Late-stage mafic dykes and pegmatite veins composed of quartz, alkali feldspar and plagioclase (both types of dyke are ~10 cm thick) are commonly found. A third type of dyke was observed in one location during the field season. This dyke consists of rounded porphyroclastic grains of plagioclase surrounded by bands of biotite containing trace amounts of garnet. Although the dyke resembled a mylonite, the contact between the dyke and the host anorthosite is sharp, and there is little to no foliation in the outcrop. Inclusions of gabbroic rock locally occur in the anorthosite. They do not have chilled margins, and sometimes have an albitic reaction rim in the host anorthosite (Plate 1E).

OXIDE MINERALIZATION

Oxide mineralization hosted by anorthositic rocks is divided into four modes of occurrence, based on field observations: 1) massive to semi-massive oxide pods, 2) disseminated oxide mineralization, 3) vein-like oxide mineralization, and 4) alternating bands of oxides and anorthosite. The oxide mineralogy is dominated by spinel series Fe–Ti oxide (magnetite–ulvospinel [Fe_2TiO_4]) and lesser trigonal series iron titanium oxides (ilmenite–hematite solid solution), where all the oxide grains range from several millimetres to centimetres in diameter. Exsolution features, such as straight-line and trellis-type exsolutions, are present in hand specimens of oxide mineralization, whereas finer grained, texturally and mineralogically more complex exsolution features are observed in thin sections (*e.g.*, Plate 2C, D).

Massive to Semi-massive Oxide Pods

Two types of oxide pods are present, based on mineral assemblages. The first type (Plate 3A–C) is composed of massive to semi-massive oxide mineralization with >90% oxide content (Plate 3A, C) and 25–90% oxide content (Plate 3B), respectively. These oxide pods vary in size with the largest pod found in one continuous outcrop measuring at least 8 m by 4.5 m (Plate 3A), and open in all directions. The pods are generally equidimensional, but locally are lens shaped or elongate. They are predominantly composed of spinel and trigonal series iron titanium oxides (titanomagnetite and hemo-ilmenite) with trace to minor pyrite, chalcopyrite and pyrrhotite (Plate 2C–E). Other minerals include aluminous spinel, calcic amphibole, clustered biotite, plagioclase, orthopyroxene, clinopyroxene and olivine. Plagioclase and orthopyroxene commonly occur as rounded single grains, and also occur in clusters. Surfaces of such oxide-rich outcrops vary in colour from steel blue to grey. The grain sizes of oxide minerals, as well as the size, prevalence and type of exsolution features are very variable (Plate 2C, D). The semi-massive to massive oxides commonly contain subhedral to euhedral hemo-ilmenite grains, subhedral aluminous spinel, and rounded pods of silicate minerals, surrounded by partially to completely recrystallized titanomagnetite. Biotite and amphibole are found as reaction rims between oxide mineralization and the host anorthosite. A portable drill was used on a massive oxide outcrop by prospectors T. Benoit and C. Coady to obtain a drillcore of unknown orientation, which indicates that the thickness of oxide mineralization might be of at least 8 m, as the lower anorthosite contact was not intersected.

The second type of oxide pods consist of semi-massive oxide mineralization dominated by ilmenite and lesser titanomagnetite. This mineralization contains abundant discrete subhedral ilmenite grains with exsolution lamellae (up to 2 mm wide) that are visible with the naked eye and highly fractured centimetre-scale euhedral to subhedral apatite crystals (Plate 3D). Other primary minerals include centimetre-scale dark-green anhedral calcic amphibole, pyroxene, minor aluminous spinel, and trace sulphides. Secondary phases, such as garnets and biotite occur at the contact between apatite-bearing oxide mineralization and the host anorthosite, as well as at the contact between apatite and oxide mineralization (Plate 2F). Rocks adjacent to the apatite-oxide-rich rocks are very coarse grained, with pyroxene crystals up to a metre long, and plagioclase crystals up to 25 cm long.

Disseminated Oxide Mineralization

Disseminated oxide mineralization (25–50% oxide), with oxide grains ranging from sub-millimetre scale to 10 cm, is the most common occurrence of oxide mineralization (Plate 4). There are two general types of disseminated mineralization that occur in similar frequency: 1) oxides associated with irregular-shaped pyroxene blebs (Plate 4A, B), and 2) those that occur disseminated in host rocks or oxides without co-forming phases (Plate 4C). Both types commonly have polymineralic, variably thick, rims of biotite, calcic and ferromagnesian amphibole, and hornblende. Oxides are dominated by hemo-ilmenite and titanomagnetite. These grains generally rim or crosscut orthopyroxene and in some cases are found as inclusions in orthopyroxene. Aluminous spinel often occurs as exsolution features in titanomagnetite, and rarely as discrete grains. Disseminated oxides commonly occur in linear arrays, and are occasionally associated with blebby sulphide minerals (pyrite + chalcopyrite + pyrrhotite) of similar size (Plate 2E).

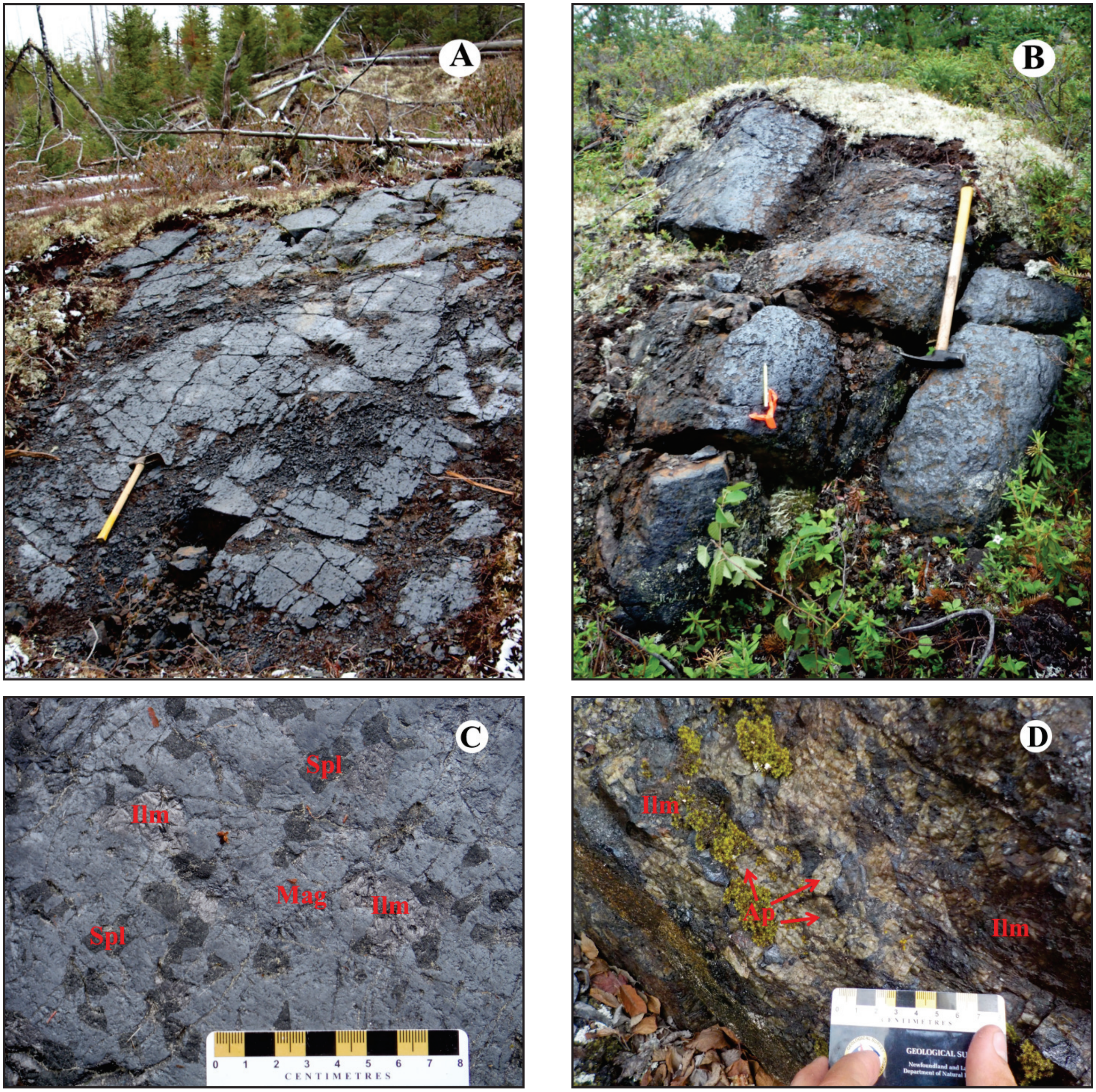

Plate 3. *Field photographs of oxide mineralization. A and B) Large outcrops of massive oxide mineralization; outcrop in A does not have constrained boundaries (the hammer is 75 cm long); C) Close-up photograph of the massive oxide outcrop shown in photograph A, exhibiting ilmenite and aluminous spinel in massive magnetite; and D) Semi-massive oxide mineralization and large subhedral to euhedral green apatite grains and interstitial ilmenite. Abbreviations: Ilm–ilmenite; Mag–magnetite; Spl–spinel; Ap–apatite.*

Vein-like Oxide Mineralization

Two styles of oxide-rich veins are common in the field area (Plate 5), both of which are dominated by titanomagnetite and hemo-ilmenite. The most common vein type (Plate 5A–C) has irregular contacts with the host anorthosite, and ranges in width from 3–30 cm. The host anorthosite commonly contains disseminated oxide blebs, and similar mineral compositions and textures as the vein-style mineralization. Rims of biotite and amphibole are developed at the contact of the veins and the anorthosite. In larger veins, inclusions of single crystals and clusters of pla-

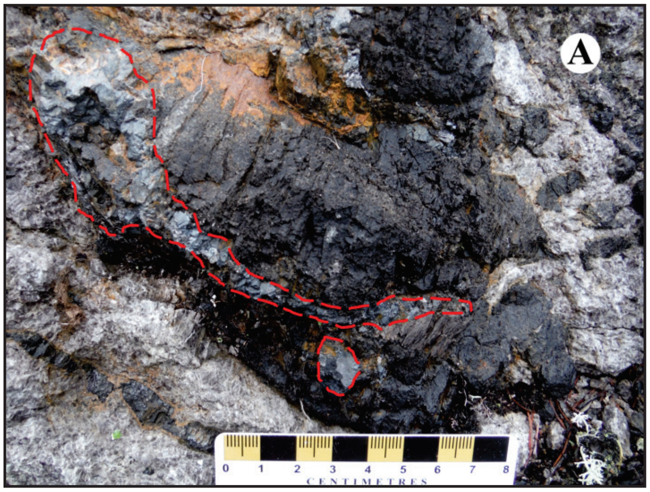

Plate 4. *Field photographs illustrating occurrences of disseminated oxide mineralization in anorthosite. A) Oxide mineralization (outlined in red) crosscutting large anhedral orthopyroxene crystal; B) Orthopyroxene grains (black) with rims of oxide mineralization (dark-grey metallic), and associated apatite (green). Note the large plagioclase crystal (dark grey) at the top left of photograph; and C) Amoeboidal oxide mineralization.*

gioclase crystals are present. These inclusions have rounded edges and relatively large coronae of biotite and amphibole. Oxide veins can be discontinuous (Plate 5B), or have their lengths disrupted by interstitial anorthosite.

The second vein type (Plate 5D) has sharp contacts with the host anorthosite and is composed of semi-massive to massive oxide. Other minerals include abundant aluminous spinel, which is pervasively altered to goethite, calcic amphibole, biotite, and single or clustered plagioclase grains. There are higher proportions of plagioclase inclusions in this mode of occurrence of oxide mineralization than in any other mode.

Alternating Oxide- and Anorthosite-banded Mineralization

Alternating bands of oxides and anorthosite mineralization represent the least common style of oxides in the area (Plate 6). This mineralization typically occurs as two or more pseudo-parallel bands of continuous massive oxide that are >30 cm wide and alternate with variably sized, thicker bands of anorthosite (Plate 6A–C). Alternating oxide and anorthosite bands were only observed in two outcrops; where a maximum of three parallel oxide bands were observed in sequence. Contacts between the oxide bands and the host anorthosite are sharp and straight on both ends. Although individual oxide bands appear similar to vein occurrences, they differ in several key manners. Contacts between oxide bands and anorthositic rocks are characterized by thinner bands of hydrous minerals, which are not observed in vein–anorthosite contacts. Moreover, oxide bands are more clearly defined and traceable along strike. Larger bands locally contain large anorthosite inclusions (Plate 6A). Oxide abundance varies within bands, from massive to net textured. Along strike, bands occasionally pinch off at surface. Mineralogically, banded oxides are very similar to sharp contact veins, containing variable amounts of titanomagnetite and hemo-ilmenite, trace chalcopyrite, pyrite and pyrrhotite. Other minerals include aluminous spinel, garnet, biotite, calcic amphibole, ferromagnesian amphibole, plagioclase and orthopyroxene.

Plate 5. *Field photographs of vein-style oxide mineralization in anorthosite (dark grey). A) Oxide vein with proximal, syngenetic oxide blebs associated with it; B) Discontinuous, thin vein of oxide mineralization; C) Thick oxide vein with irregular contacts with anorthosite; and D) Large vein of oxide mineralization having sharp contacts with a gabbronorite host rock.*

Magmatic Sulphide Mineralization

In addition to Fe–Ti–V and apatite-rich oxide mineralization, minor amounts of low-grade disseminated sulphide mineralization also occur in the CCRA. The examination of hand specimens and preliminary petrographic observations show the dominant sulphide minerals to be pyrite, chalcopyrite and pyrrhotite, with pentlandite locally occurring in the pyrrhotite. In addition to the disseminated sulphide mineralization, sulphide veins were found in two large rounded

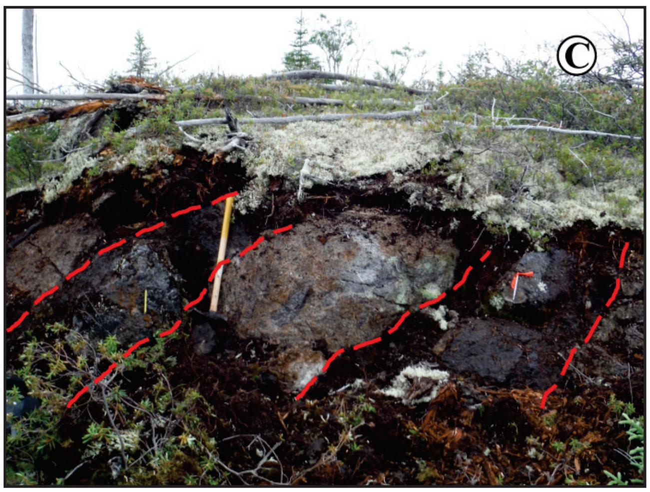

Plate 6. *Field photographs of alternating bands of oxide and anorthosite. A) A large outcrop with three conformable bands of massive oxide mineralization as indicated by the arrows, alternating with anorthosite layers. Inset box represents the area shown in photograph B; B) Detail of a band of oxide mineralization (dark grey) shown in A and having sharp contacts to the host anorthosite (light grey); and C) An outcrop having two parallel layers of massive oxide mineralization (dark grey, outlined in red) in sharp contact with the host anorthosite (light grey).*

gossaniferous boulders within 10 m of each other, with the veins crosscutting anorthosite host rocks that display similar macroscopic features to that of nearby outcrops. Whole-rock lithogeochemical data of a sulphide vein sample (this research) yielded low metal contents (<1% combined Ni and Cu).

CONCLUSIONS AND FUTURE WORK

Oxide mineralization is widespread within the NWRA of the CCRA, and is hosted in anorthosite *(sensus stricto)* and gabbronorite. Four modes of mineralized occurrences were observed: 1) oxide pods, 2) oxide veins, 3) disseminated oxides, and 4) alternating bands of oxide and anorthosite. Oxide minerals are mainly titanomagnetite and hemo-ilmenite, and have complex exsolution textures, which are visible in both hand specimen in most cases and thin section. Oxide mineralization is commonly associated with sulphide minerals (dominantly pyrite, chalcopyrite, and pyrrhotite). Apatite-bearing oxide mineralization occurs locally in the study area, specifically in a pseudo circular pod with a medium-grade aeromagnetic anomaly.

Detailed mineralogical, textural, and geochemical studies will be undertaken during the course of the MSc. thesis project. This will include detailed petrographic descriptions of polished thin sections, as well as scanning electron microscopy (SEM)-based mineral liberation analysis (MLA). Electron microprobe analysis (EMPA) will be used to determine the chemical compositions, specially the Ti and V contents of the oxide minerals. Subsets of samples will also be selected for precious metal analysis (specifically PGEs and Au), for which no present data exists. Depending on the presence of suitable minerals, geochronology may also be attempted. Results will be compared to those from other such mineralized zones across Labrador (data currently being collected by M. Fonkwe, A. Kerr and J. Conliffe).

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