Preliminary results of summer 2018 fieldwork focused on the Chibougamau transect area as part of the Metal Earth project

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INTRODUCTION

Funded in part by the Canada First Research Excellence Fund, the Metal Earth project, of which this preliminary report is part, seeks to determine the reasons why certain Archean greenstone belts, including the Abitibi belt, are richer in minerals than others despite their similar surficial geology. The differences between these belts are potentially related to their architecture at depth and their evolution. Thus, it is critically important to acquire a good understanding of the faults and sedimentary basins associated with these features.

This report aims to present the status of mapping done in the Chibougamau transect area during summer 2018. It provides an outlook on the way the work was carried out and explores more fully the Chebistuan Formation basin and its northern limit, the Barlow Fault. This paper also serves as an introduction to four preliminary reports describing the work done by M.Sc. students in the Chibougamau transect area. This report starts with a presentation of the regional geology to provide context for the preliminary results from the transect area as well as for those presented in the research studies undertaken by the M.Sc. students.

The Chibougamau transect is located at the northeastern end of the Abitibi Subprovince, an Archean greenstone belt (Figure 1). The generally north–south-striking transect extends 162 km, from the Nord road to logging road R-1009 south of the town of Chapais, passing near the City of Chibougamau. In geological terms, it extends from the Opatica Subprovince near the limit with the Abitibi Subprovince, cuts four synclines and three anticlines oriented east–west and forming one vast synclinorium, and ends just south of the fourth syncline occupied by the Caopatina Formation sedimentary basin.

REGIONAL GEOLOGY

The Chibougamau area is described as a greenstone belt dominated by volcanic and sedimentary rocks cut by various intrusions (Daigneault and Allard, 1990; Leclerc et al., 2015). Most of the geological history unfolded from ~2730 to 2691 Ma (Daigneault and Allard, 1990; Leclerc et al., 2015), but the presence of older volcanic rocks of the Chrissie and Des Vents formations, dated between 2798.7 and 2759 Ma (Mortensen, 1993; Davis et al., 2014) was locally documented. Chibougamau area stratigraphy is divided into two groups: the Roy Group (2730–2721 Ma), which comprises two volcanic cycles (Daigneault and Allard, 1990; Leclerc et al., 2011), and the Opémisca Group (<2691 Ma), which hosts sedimentary deposits (Dimroth et al., 1985). The intrusions in the area range from synvolcanic to post-tectonic.

The first volcanic cycle consists of the Obatogamau Formation overlain by the Waconichi Formation. The Obatogamau Formation is dominated by submarine basaltic to andesitic volcanic flows interbedded with minor felsic rock, exhalites and chert denoting pauses in volcanic activity. This formation is characterized by the presence in some flows of plagioclase glomerocrysts, which can represent over half the unit (Allard and Gobeil, 1984). The age of the Obatogamau Formation has not been determined but it is interpreted as the floor of the Chibougamau area. The Waconichi Formation consists of andesitic to rhyolitic volcaniclastic-facies–dominated volcanic rocks (Daigneault and Allard, 1990). It corresponds to several small eruptive centres and provides a favorable setting for volcanogenic massive sulphides. The formation was emplaced ~2730–2727 Ma (Mortensen, 1993; Leclerc et al., 2011). The early Chrissie and des Vents formations were locally documented below the base of the first volcanic cycle.

The second volcanic cycle begins with the Bruneau Formation (Leclerc et al., 2011), or Gilman Formation as it was previously known (Daigneault and Allard, 1990). It consists of basaltic to andesitic volcanic flows lying unconformably upon the Waconichi Formation. Above it lies the Blondeau Formation (<2721 Ma; Leclerc et al., 2012), comprising felsic volcaniclastic rocks, argillite and sulphidic horizons, as well as the Bordeleau Formation, a lateral sedimentary equivalent to the Blondeau Formation consisting of feldspathic sandstone and turbidite (Caty, 1978, 1979; Dimroth et al., 1983).

The Opémisca Group lies uncomformably on the Roy Group. It is dominated by sedimentary deposits and comprises the Stella, Haüy and Chebistuan formations. Stella Formation consists mostly of conglomerate and sandstone (Caty, 1975; Dimroth et al., 1983). Haüy Formation lies conformably upon it and is interdigitated with it (Dimroth et al., 1985). This formation, predominantly consisting of equal parts of conglomerate and sandstone, differs from the Stella Formation in that it contains trachytic mafic lavas between the sedimentary sequences (Picard and Piboule, 1986; Daigneault and Allard, 1990). The Chebistuan Formation is equivalent to the Stella Formation that lies within the Waconichi syncline, north of the Chibougamau area.

The Chibougamau area is noteworthy for its many intrusions that cut the stratigraphic sequence. The tonalite-trondhjemite-granodiorite series–type synvolcanic intrusions differ from the syn- to post-tectonic granodiorites. The Lac Doré Complex, a large polyphase and layered mafic intrusion similar in age to the Waconichi Formation (Daigneault and Allard, 1990; Mortensen, 1993), consists of anorthosite, pyroxenite, gabbro, granophyric tonalite and magnetite units prospective for vanadium mineralization (Allard, 1976). This intrusion hosts most of the porphyritic Cu-Au deposits of the Chibougamau mining camp, which are genetically related to an intrusive phase of the Chibougamau Pluton. The latter was emplaced within the Lac Doré Complex (Racicot, 1980). This polyphase intrusion is coeval with the second volcanic cycle (2728.3–2727 Ma; Mortensen, 1993) and is dominated by tonalites and diorites. The Cummings Complex is the same age as the Chibougamau Pluton (Chown et al., 1992) and consists of three ultramafic to mafic sills (from the earliest to the most recent: Roberge, Venture and Bourbeau) aged <2721 Ma (Leclerc et al., 2012). The Eau Jaune Complex is located at the base of the Obatogamau Formation. This undated polyphase assemblage of diorite and tonalite is spatially related to the Lapparent Massif. Finally, the Chevrillon Pluton, a porphyritic monzodiorite containing feldspar, stands out among the diverse syn- to post-tectonic intrusive rocks of the area and cuts the Chebistuan Formation.

The Abitibi greenstone belt is metamorphosed to greenschist-facies, locally reaching upper amphibolite facies, especially near syn- to late tectonic intrusions (Daigneault and Allard, 1990; Benn et al., 1992). The ductile-style deformation is multi-phased in the Chibougamau area (Daigneault and Allard, 1990; Daigneault et al., 1990). In particular, deformation is characterized by east–west to southeast–northwest folds associated with regional foliation corresponding to a series of synclines and anticlines. They incorporate folds with no specific foliation, which correspond to surface rock burial and pluton upward displacement. These east–west folds are accompanied by faults that also strike east–west on the border of the sedimentary basins. These faults create large-scale deformation zones and are interpreted to have undergone reverse movement. Another generation of younger, discrete and brittle faults striking northeast–southwest show sinistral movement. Finally, deformation associated with the Grenville Front, a major structure resulting from the collision between the Abitibi Subprovince and the Grenville Province to the west, overprints the Archean structural styles and appears as north-northeast–south-southwest faults, ductile fabrics and a metamorphic grade that increases as the border between these two ensembles is approached (Daigneault and Allard, 1994).

WORK COMPLETED

Summer 2018 fieldwork covered the whole length of the transect. The major focus was on the four large parts of the transect corresponding to the issues targeted in the M.Sc. research projects: 1) the Chebistuan Formation to the north, and related Chevrillon Pluton and Barlow Fault; 2) the Lac Doré Complex granophyre; 3) the Obatogamau Formation volcanic rocks (south of the Chibougamau Pluton); and 4) the Lapparent Massif and Eau Jaune Complex. In total, during this summer's fieldwork 831 stations were described and 612 samples collected. Of these samples, six of the seven that could be analyzed using U-Pb zircon geochronology come from yet undated formations or intrusive rocks.

CHEBISTUAN FORMATION AND BARLOW FAULT

The Chebistuan Formation is located in the Waconichi syncline (Daigneault and Allard, 1990) and is bordered to the north by the Barlow Fault, an east–west-striking structure that separates the formation from the rest of the Abitibi Subprovince (Figure 2). This structure is historically interpreted as dipping to the south, being several hundred metres thick, and having experienced moderate deformation and unknown movement (Daigneault, 1996). During summer 2018 fieldwork, many outcrops within the Chebistuan Formation and proximal to the fault were documented, thus helping improve understanding about this fault, its influence regionally and the timing of deformation events north of the Chibougamau area. The Barlow Fault appears to show significant lateral variation based on the changes in dip values and lithological units occurring on both sides of the fault. The remainder of this section discusses the Chebistuan Formation, then goes on to describe the structural styles associated with the Barlow Fault.

Chebistuan Formation

The Chebistuan Formation sedimentary basin covers more than 150 km in an east–west direction and reaches ~30–50 km in width. The summer 2018 stations represent two main types of lithological assemblages: conglomerate-sandstone and argillite-siltstone. The conglomerates, systematically polymictic and jointed, appear as poorly sorted or unsorted metric beds, with rounded fragments (Figure 3a). These fragments are mainly composed of mafic volcanic rocks and intermediate–felsic intrusive rocks. Some beds also contain sedimentary rock and massive sulphide fragments. Locally, certain types of fragments proportionally predominate. The bedding can at times be inferred from the variation in the size of fragments. Sandstone and siltstone beds are decametric, well sorted and most often massive. The coarser clasts are composed of millimetric quartz and feldspar crystals. In some beds, grading displays many basin-wide polarity reversals. Argillites form centimetric beds that constitute sequences several metres thick, with generally well-defined bedding.

The bedding of the sedimentary rocks is generally oriented east–west and dips steeply. These rocks display penetrative axial-planar schistosity. The related stretching lineation follows dip direction. Schistosity is better developed in the conglomerate than in the other types of sedimentary rocks. The finer sedimentary rocks are massive and their quartz-feldspar elements are less subject to flattening associated with schistosity, whereas foliation in argillite is axial planar to bedding. Flattening is generally planar but proximal to the Barlow Fault, it becomes essentially linear (Figure 3b). Basin-wide polarity reversals suggest an alternation of small folds associated with the Chapais syncline. Foliation orientation is disturbed near the Chevrillon Pluton. All sedimentary rocks are of upper greenschist-facies metamorphic grade, or even amphibolite-facies, as indicated by the presence of amphibole porphyroblasts in mafic fragments (Figure 3b). Based on field data, metamorphic grade varies across the basin. The southern part of the basin presents a weaker metamorphic facies (greenschist), whereas the northern border reaches amphibolite facies proximal to the Barlow Fault. Within the basin, metamorphic facies is influenced by proximity to intrusions associated with the Chevrillon Pluton that produce an amphibolite-facies contact metamorphic halo.

Barlow Fault

In the study area, the western part of the Barlow Fault brings the Chebistuan Formation in contact with mafic flows to the north (Daigneault and Allard, 1990). The east–west-striking fault is associated with a steepening of the regional schistosity to a subvertical dip, a more pronounced flattening of fragments in conglomerate and a strong stretching lineation trending 70° toward the east. The deformation envelope associated with the fault is at least 500 m wide. Mapping during summer 2018 revealed that the trace of the Barlow Fault is located several hundred metres north of its historic position (Daigneault and Allard, 1990). The volcanic rocks located to the north are interpreted as belonging to the Bruneau Formation (Daigneault and Allard, 1990). However, summer fieldwork made it possible to document a volcanic sequence containing centimetric plagioclase phenocrystals within the pillowed flows, which are characteristic of the Obatogamau Formation, and located less than 250 m north of the fault. The thickness of the Bruneau Formation has been estimated at ~1200 m in this area (Daigneault and Allard, 1990). This summer's results suggest that the Bruneau Formation is far thinner in this sector (<250 m), even inexistent. Polarity indicators in volcanic rocks, as well as in sedimentary rocks nearest to the fault, are oriented to the south.

The transition zone between the western and central parts of the Barlow Fault presents a setting similar to that of the western part, and represents the contact between the Chebistuan Formation and volcanic rocks. However, the fault dip tends to plunge steeply toward the south (70°) instead of being vertical, as in the western part. Here again, the fault is located higher north than its historical trace, so much so that the intrusive rocks associated with the Chevrillon Pluton are located entirely within the Chebistuan Formation, although they had been interpreted as cutting the Barlow Fault and volcanic rocks to the north (Daigneault and Allard, 1990).

The central part of the Barlow Fault constitutes a specific environment very different from the rest of this structure. Over 10 km, the fault brings the Chebistuan Formation in contact with various lithological units (volcanic flows, sedimentary and volcaniclastic rocks, sills) of the Blondeau Formation and Cummings Complex. These rocks have no lateral continuity and form a lens 2 km thick bordered to the north by the volcanic rocks of the Bruneau Formation. The northern and southern limits of this lens are highly deformed and strike N60–N110°. The shallow dip (average 20–30°) can reach up to 15° in the more deformed zones, where protoliths are difficult to identify (Figure 3c). The structural style in this section is observed over a width exceeding 3 km, due in part to the shallow plunge of the fault relative to the horizontal plane. One station located in the southern part of the fault exposes a CS-type shear sense indicator, suggesting reverse movement with a moderate degree of certainty. Mafic volcanic rocks of the Bruneau and Obatogamau formations located north of the Barlow Fault are metamorphosed to amphibolite facies, which is characterized by banded rocks and millimetric amphibole porphyroblasts, significant recrystallization and primary textures that are poorly preserved, or have not been preserved (Figure 3d). The Cummings Complex sills appear hardly deformed in the field but nevertheless present metamorphism indicators of upper greenschist- or amphibolite-facies grade (recrystallization structure and porphyroblasts). The Blondeau Formation volcano-sedimentary rocks present similar characteristics, whereas the metamorphic grade of the Chebistuan Formation rocks, which are highly deformed although the primary textures are preserved, appears to reach the upper greenschist facies. Near the Barlow Fault (<20 m), rocks are chloritized; however, they still present amphibolite-facies characteristics (e.g., amphibole porphyroblast relicts, signs of recrystallization). The overprinting of chloritization suggests that a degree of lower greenschist- facies retrograde metamorphism is associated with the fault.

CONCLUSION AND FUTURE WORK

Summer 2018 fieldwork covered the entire Chibougamau transect along more than 170 km. The north–south-striking transect extends across a series of regional synclines and anticlines, from the border with the Opatica Subprovince to the north, covering the whole length of the greenbelt in the Chibougamau area. Research focused specifically on sectors associated with M.Sc. projects and on the sedimentary basin related to the Chebistuan Formation in the northern part of the transect.

The Chebistuan Formation is an important sedimentary basin within a syncline in the northern part of the Chibougamau area. It is characterized by conglomerate-sandstone and sandstone-argillite sequences that are reminiscent of Timiskaming-basin–type fluvial environments of the western part of the Abitibi Subprovince. Basin structure is dominated by sequences of east–west oriented, probably tight or isoclinal folds with a strongly developed regional schistosity. The rocks were metamorphosed to at least upper greenschist-facies grade during burial and folding events that affected the region. This pattern is made even more complex by the emplacement of the Chevrillon Pluton, which induced a deflection of the regional schistosity, as well as an increase in the metamorphic grade nearby. The northern border of the basin is occupied by the Barlow Fault characterized by its footprint several hundred metres in size, its overall east–west direction and its highly variable dip, ranging from 15° toward the south to subvertical. This structure marks the limit between two metamorphic domains and brings the rocks belonging to several formations resulting from two volcanic cycles in contact with the Chebistuan Formation. The apposition of a higher-grade metamorphic facies in the north relative to that in the south suggests normal movement occurring after metamorphism; however, kinematic indicators suggest instead that reverse movements occurred.

The Chebistuan Formation and the Barlow Fault will be the focus of a postdoctoral research project based on the structural basin-wide analysis resulting from the summer 2018 fieldwork and on compilation of existing data. At the same time, mapping of metamorphism will be done using mineralogical assemblages as well as specific minerals, such as amphiboles, to determine the prevailing pressure and temperature conditions. The aim is to determine the tectonic history of the basin and the influence of the Barlow Fault in regional deformation events.

At the transect scale, fieldwork will focus on further documenting the major geological contacts in the Chibougamau area, including those with sedimentary basins, and the limit between the two volcanic cycles to determine their nature (unconformity, faults). The Caopatina basin in the south is also a privileged target, as is the nature of its northern and southern borders.

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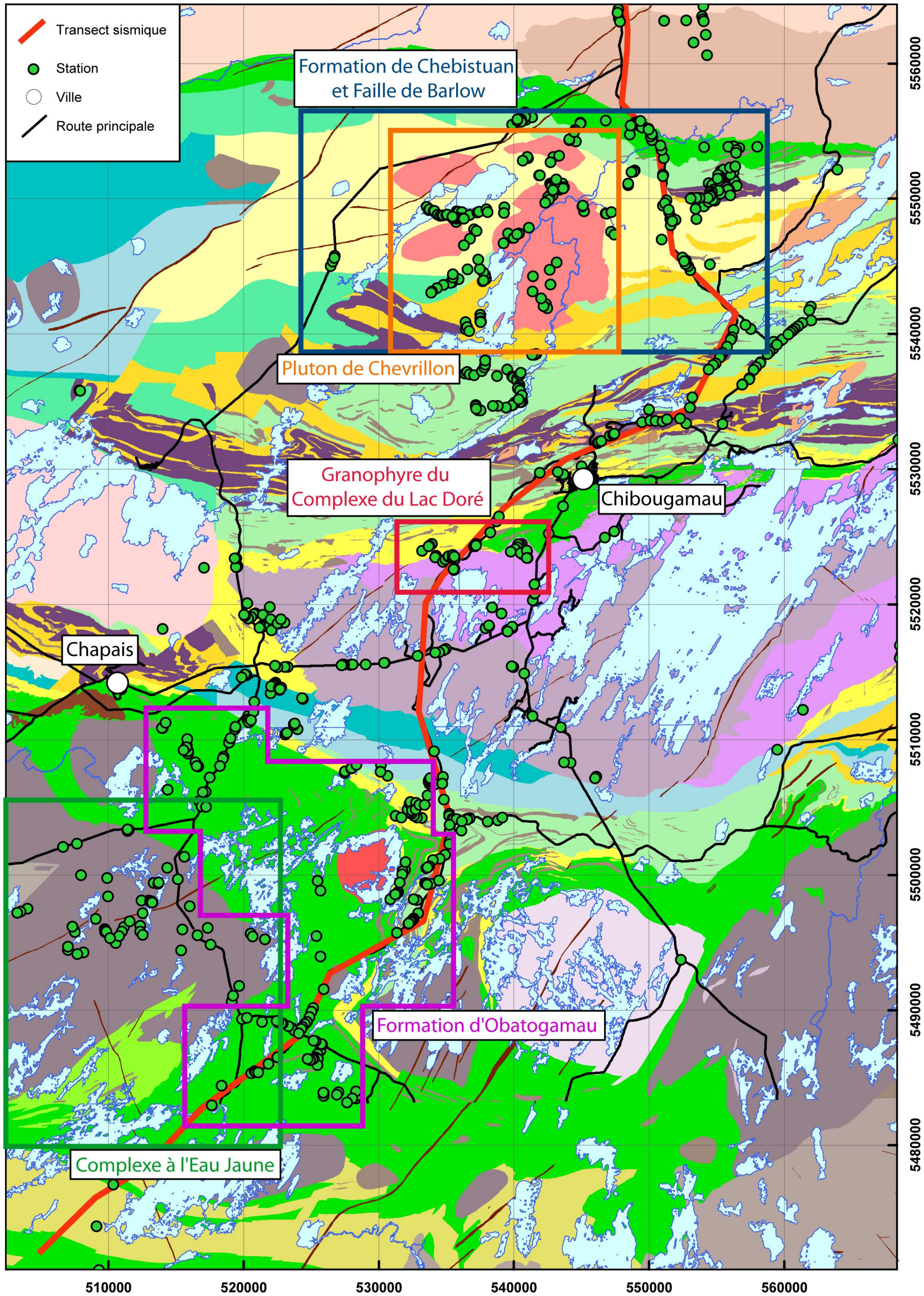

Figure 1:. Regional geology of the Chibougamau area (from SIGÉOM, 2018), showing the seismic survey trace as well as the study sectors in more detail. The green dots correspond to the 2018 fieldwork observation stations. Legend can be found in Appendix A.

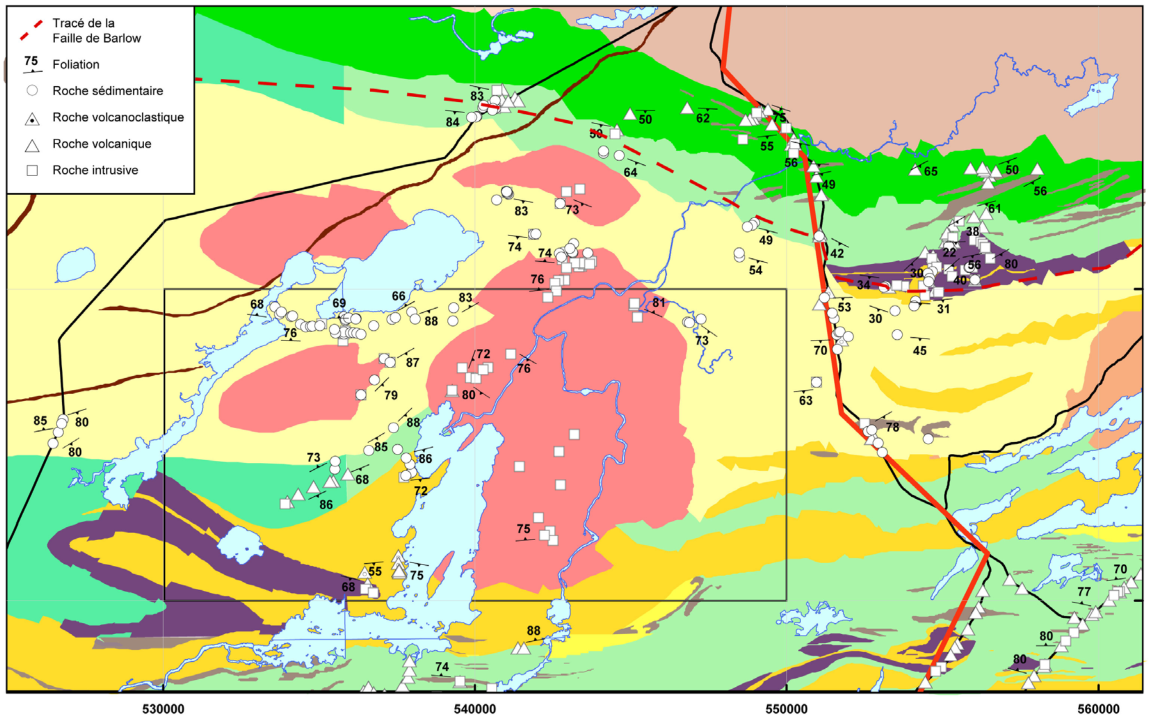

Figure 2: Geology of the Chebistuan Formation basin (Daigneault and Allard, 1990; Leclerc et al., 2015). Legend can be found in Appendix A.

Figure 3: Lithological units and structural styles associated to the Barlow Fault: **a)** conglomerate-sandstone sequence of the Chebistuan Formation, with generally polymictic, jointed conglomerates containing rounded fragments; **b)** polymictic conglomerate with fragments that become progressively more flattened nearing the Barlow Fault and more mafic fragments that show the distinctive salt-and-pepper texture associated with amphibolite-facies metamorphism; **c)** structural style of the central part of the Barlow Fault in mafic flows, characterized by a dominant schistosity, shallow dip and a well-developed stretching lineation; **d)** amphibolite-facies metamorphosed mafic volcanic rocks north of the Barlow Fault, which show banding, recrystallization and many amphibole porphyroblasts, as well as stretched pillow margins highlighted by greenish chloritization.

APPENDIX A – GEOLOGICAL LEGEND

Formations volcaniques et sédimentaires

- Formation de Chibougamau
- Dyke protérozoïque
- Formation de Chebistuan
- Formation d'Haüy
- Formation de Stella
- Formation de Caopatina
- Formation de Blondeau
- Formation de Bruneau
- Formation de Guilman
- Formation de Waconichi
- Formation d'Obatogamau
- Formation de Chrissie
- Formation des Vents

Intrusifs synvolcaniques

- Complexe de Cummings
- Pluton de Chibougamau
- Complexe du Lac Doré
- Pluton de Lapparent
- Pluton de La Dauversière

Intrusifs syntectoniques

- Pluton de Chevrillon
- Pluton de Barlow
- Pluton d'Opémisca
- Pluton de Muscocho

- Autre intrusif

- **Sousprovince de Grenville**
- **Sousprovince d'Opatica**