Mapping in the southern part of the Chibougamau transect, focusing on the stratigraphy of the Obatogamau Formation

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INTRODUCTION

This report presents the main findings of mapping done in the Muscocho syncline area and focuses specifically on the Obatogamau Formation, which is the subject of a thematic M.Sc. thesis at the Université du Québec à Chicoutimi.

The Obatogamau Formation is a volcanic unit that covers a wide area located in the Chibougamau area. It was defined by Cimon (1977) as being composed mainly of mafic lava that could contain 0–15% centimetric plagioclase macrocrystals. It extends over a distance of over 100 km from the Grenville Province front in the east to the Desmaraisville sector in the west (Allard and Gobeil, 1984; Mueller et al., 1989)

The formation makes up one third of the exposed rocks along the geophysical-geological Chibougamau transect studied as part of the Metal Earth project. The tholeiitic mafic lavas range in composition from basalt to basalt-andesite (Ludden et al., 1984; Leclerc et al., 2011). However, vertical and lateral variations in chemical composition within the 3–4 m thick sequence have seldom been documented. Also, the origin and conditions controlling the formation of the plagioclase macrocrysts are poorly constrained (see Midra, 1989; Polat et al., 2018a, b). In addition, the nature of the thin felsic layers incorporated in mafic lava has not been documented. Finally, the age of the Obatogamau Formation has not been directly determined and is therefore poorly constrained since this formation lies between the Chrissie and des Vents formations (ca. 2.80–2.76 Ga) and the Waconichi Formation (ca. 2.73 Ga; Mortensen, 1993; David et al., 2011; Davis et al., 2014; Leclerc et al., 2017). Efforts to better document the Obatogamau Formation are therefore required to better understand the manner in which the main volcanic cycles observed in the Chibougamau area were emplaced.

The Chibougamau transect passing in the heart of the Muscocho Syncline (Figure 1), the mapping and sampling carried out during the summer 2018 fieldwork had to be done approximately 20 km west of the syncline to document the Obatogamau Formation from the base to the top. The Obatogamau Formation has also been documented in an area near the northern section of the transect, where it is exposed. Concurrently, mapping was carried out within the Muscocho Syncline to improve the knowledge about the volcanic successions exposed in that location. Finally, work was also started in the southern area of the Muscocho Syncline to better document a band of east–west-striking intermediate–felsic volcanoclastic rocks (Figure 1) recently related to the Waconichi Fomation (F. Leclerc, pers. comm., 2018).

REGIONAL GEOLOGICAL SETTING

The Roy Group, the stratigraphy of which was recently revised, makes up the major portion of the volcanic assemblage in the Chibougamau area (Leclerc et al., 2011, 2017). It consists of two volcanic cycles, each one comprising two formations. Before the revision, these formations were, from the base to the top, the Obatogamau and Waconichi formations in the case of the first volcanic cycle, followed by the Gilman and Blondeau formations for the second (Daigneault and Allard, 1990). When they revised the Roy Group stratigraphy, Leclerc et al, (2008, 2011) correlated the base of the Gilman Formation (old base of the second cycle), or David Member, with the top of the Obatogamau Formation based on geochemical and geochronological considerations. In addition, these authors proposed renaming the remaining portion of the Gilman Formation, which is now known as the Bruneau Formation (new base of the second cycle).

The Muscocho Syncline (Figure 1) is a north–south-striking structure that predates regional D_2 deformation (Daigneault et al., 1990; Legault, 2003). The transition between the first and the second volcanic cycle was observed in this structure. In addition, interdigitations between the top of the Obatogamau Formation and the base of the Waconichi Formation occur at that location. The southern end of the syncline is shielded by the Verneuil Pluton (Figure 1).

The band of volcaniclastic rocks located south of the Muscocho Syncline has recently been assigned to the Waconichi Formation based on geochronological data (F. Leclerc, pers. comm., 2018) under the name of Winchester Member. This band of volcaniclastic rock and the mafic lava located to the north and south were previously assigned to the Obatogamau Formation.

The region contains several anorthosite-bearing layered intrusions that could be comagmatic with the Obatogamau Formation lava, such as the Lac Doré and Rivière Opawica complexes (Midra, 1989; Polat et al., 2018a, b). These intrusions are typically found in the northern part of the Abitibi Subprovince in Quebec (Dimroth et al., 1982; Card, 1990).

The rocks belonging to the volcanic cycles older than those of the Roy Group, i.e., Chrissie and des Vents formations (dated by David et al. [2011] at 2791.4 ±3,7 Ma, by Davis et al. [2014] at 2798.7 ±0.7 Ma and by Mortensen [1993] at 2759 ±2 Ma),which lie stratigraphically below the Obatogamau Formation (Leclerc et al., 2017), are located west of the Muscocho Syncline, along the borders of the Eau Jaune Complex and the Lapparent Massif (Figure 1). It is therefore coherent to map the Obatogamau Formation along a transect starting at the base of the formation and following it to the top, from the Eau Jaune Complex to the Waconichi Formation.

WORK COMPLETED

Stratigraphy of the Obatogamau formation

West of the Chibougamau transect (Figure 1), base to top transect mapping of the Obatogamau Formation allowed sampling of most of the lava flow sequence.

This transect also made it possible to document several interruptions in mafic volcanism. These interruptions appear as layers of chert, argillite and pyrite-bearing graphitic tuff. These layers have been identified on two outcrops located in the lower and middle/upper parts of the lava sequence, respectively.

Another major interruption was observed outside the transect mapping area. It is located near the western border of the Muscocho Syncline (no. 1; Figure 1), in the middle part of the sequence. It appears as massive rhyolitic layers and a thin dacitic layer incorporated in the basalts (Figure 2). The rhyolite was sampled for the purpose of radiometric U-Pb dating on zircon. Given the interdigitations observed between the Obatogamau and Waconichi formations (Cimon, 1977), the expected age should be similar to that of the overlying Waconichi Formation (2728.7 ±1.0 Ma, Leclerc et al., 2011; 2729.7 ±1.9 Ma, Mortensen, 1993). However, if emplacement of the Obatogamau Formation occurred over a long period of time, this felsic unit could be older.

Finally, an additional interruption was identified near the northern part of the Chibougamau transect, appearing as crystalline tuff and ash tuff incorporated between two porphyritic lava flows. This interruption being located far from the main study area, it is not covered in this report.

The quantity of plagioclase macrocrysts varies considerably between flows observed in the field. Certain aphyric flows are in contact with flows that may contain up to 20% macrocrysts (Figure 2b). The size of the macrocrysts can also vary, from 0.5 cm to more than 4 cm. In 1977, Cimon reported plagioclase macrocryst proportions varying from 1 to 3% in the porphyritic flows of the lower part of the sequence, which reached 15% in the middle part and less than1% in the upper part (at the level of the Township of Queylus, east of the Muscocho Syncline). Similar variations were observed along the transect carried out west of the Chibougamau transect.

The transect mapping area shows little deformation characterized by changes in the orientation of polarity in pillows and by a weakly to strongly developed schistosity. Where it was observed, the pillow polarity varied from north-northeast and northeast. Schistosity observed in the basalts showed two preferential orientations, one northwest–southeast oriented and the other northeast–southwest oriented, with subvertical dips. Lack of outcrops meant insufficient data was collected to determine the occurrence of potential structural repetitions of this sequence

Volcanic succession of the Muscocho Syncline

Mapping was done near the Muscocho Pluton, on the western limb of the Muscocho Syncline (Figure 1). Three formations follow each other from the centre of the syncline to the pluton: the Bruneau/Gilman Formation, consisting mainly of basalt and andesite; the Waconichi Formation (Andy Member), consisting mainly of mafic–intermediate lapilli tuff; and the Obatogamau Formation. Many dioritic dikes associated with the Muscocho Pluton crosscut the nearby volcanic rocks.

East of the Muscocho Pluton, layers of lapilli tuff, intermediary crystal tuff and ash tuff were observed within the mafic lava of the Obatogamau Formation (no. 2; Figures 1, 2c), which exhibits amphibolite facies metamorphism. However, this lava contains feldspar macrocrysts that are inordinately small (<5 mm) for the Obatogamau Formation (Figure 2d). In addition, analysis of the mafic lava using a portable X-ray fluorescence spectrometer (µXRF) revealed inordinately high Zr contents for the Obatogamau Formation (Table 1). Similar contents were measured in volcanic rocks of the Waconichi Formation in the course of analyses carried out along other sectors of the Chibougamau transect. The lava and tuff layers are interpreted preliminarily as part of the Waconichi Formation, where it and the top of the Obatogamau Formation are interdigitated.

Work in the sector occupied by the Winchester Member has started. Diverse layers of tuff, varying from crystal tuff to lapilli tuff and tuff blocks, have already been described and sampled

(Figure 2e; no. 3, Figure 1). An age matching that of the Waconichi Formation has recently been obtained for this member (F. Leclerc, pers. comm., 2018). In addition, the mafic lavas located south of the member display polarity orientations to the south (Figure 2f). The lavas are thought to be stratigraphically located above the Waconichi Formation and to belong to the Bruneau/Gilman Formation (second volcanic cycle of the Roy Group).

FUTURE WORK

Sufficient data was collected during the work to characterize the Obatogamau Formation using in situ lithogeochemical analyses. Results from the lithogeochemical analyses will be combined with data compiled from the literature and from the SIGÉOM database (SIGÉOM, 2016) to document the heterogeneity (vertical and, to some extent, lateral) of the Obatogamau Formation lava sequence and to characterize its mantle source. In situ analyses will be carried out on plagioclase macrocrysts to document their growth and to characterize the magmatic chamber in which they formed. Similar analyses will be done on plagioclase macrocrysts from the Lac Doré and Opawica complexes for the purpose of comparison. An electron scanning microscope and, possibly, a laser ablation inductively-coupled plasma mass spectrometer will be used to perform these in situ analyses.

The mapping planned for summer 2019 should focus on the area south of the Muscocho Syncline to complete the data sampling started in the Winchester Member sector. Work will be concentrated on mapping of units that are part of the second volcanic cycle of the Roy Group and on the structural geology of the area. Indeed, the polarity observed in the Muscocho Syncline lavas is oriented toward the east or the west (depending on the limb of the syncline), but no structural data can explain the transition to the south-striking polarity that was observed on mafic lava outcrops located south of the Winchester Member.

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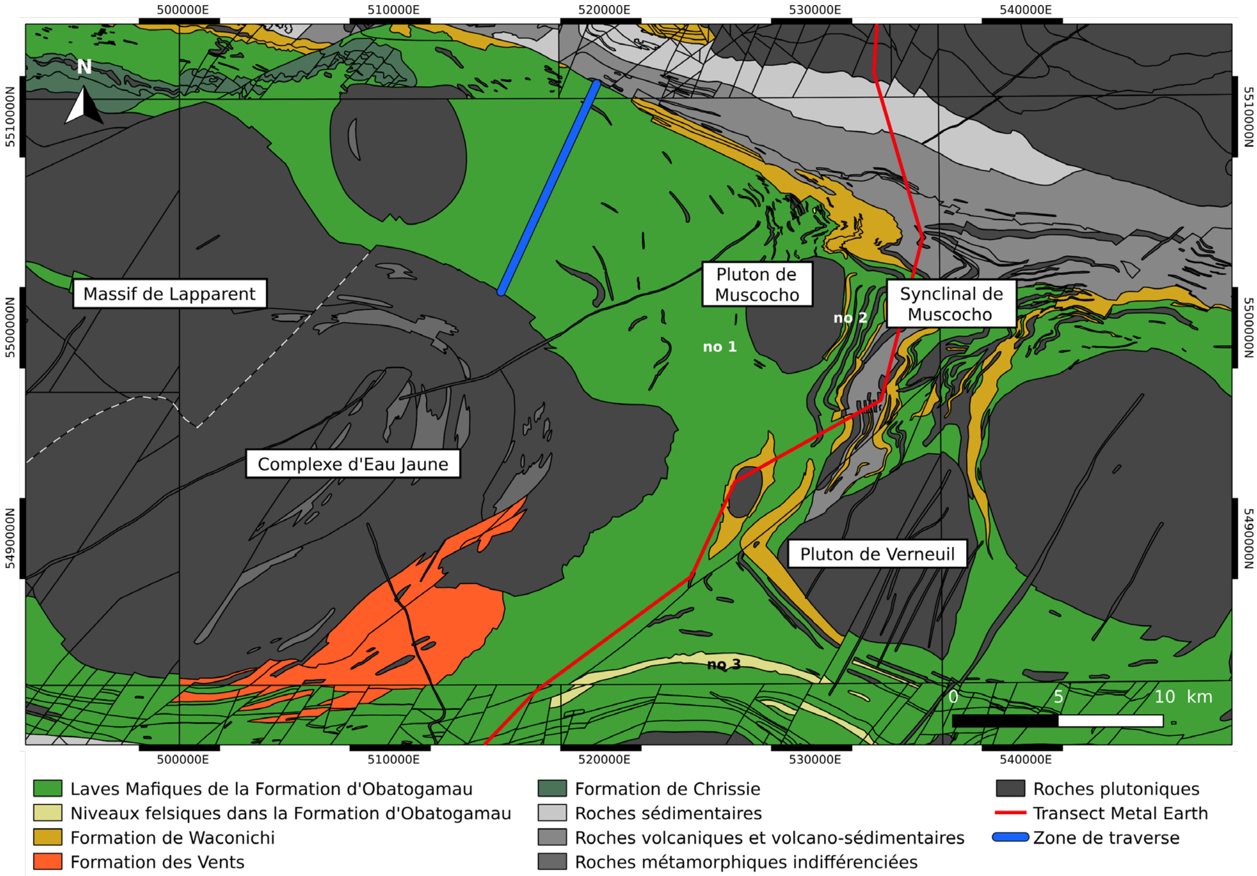

Figure 1. Map of the sector covered by summer 2018 fieldwork, compiled from the SIGÉOM database (SIGÉOM, 2016). Due to the age of data, the Winchester Member appears as a felsic level of the Obatogamau Formation. The Chibougamau transect is indicated in red; the area selected for transect mapping, from base to top, of the Obatogamau Formation, is shown in blue. Site no. 1 (centre of the number) corresponds to the location of massive rhyolitic levels observed in the Obatogamau Formation. Site no. 2 corresponds to tuff levels interpreted as belonging to the Waconichi Formation interdigitated with the Obatogamau Formation. Site no. 3 corresponds to the location of a felsic lapilli tuff and block tuff within the Winchester Member. Coordinate system UTM NAD 83, Zone 18N.

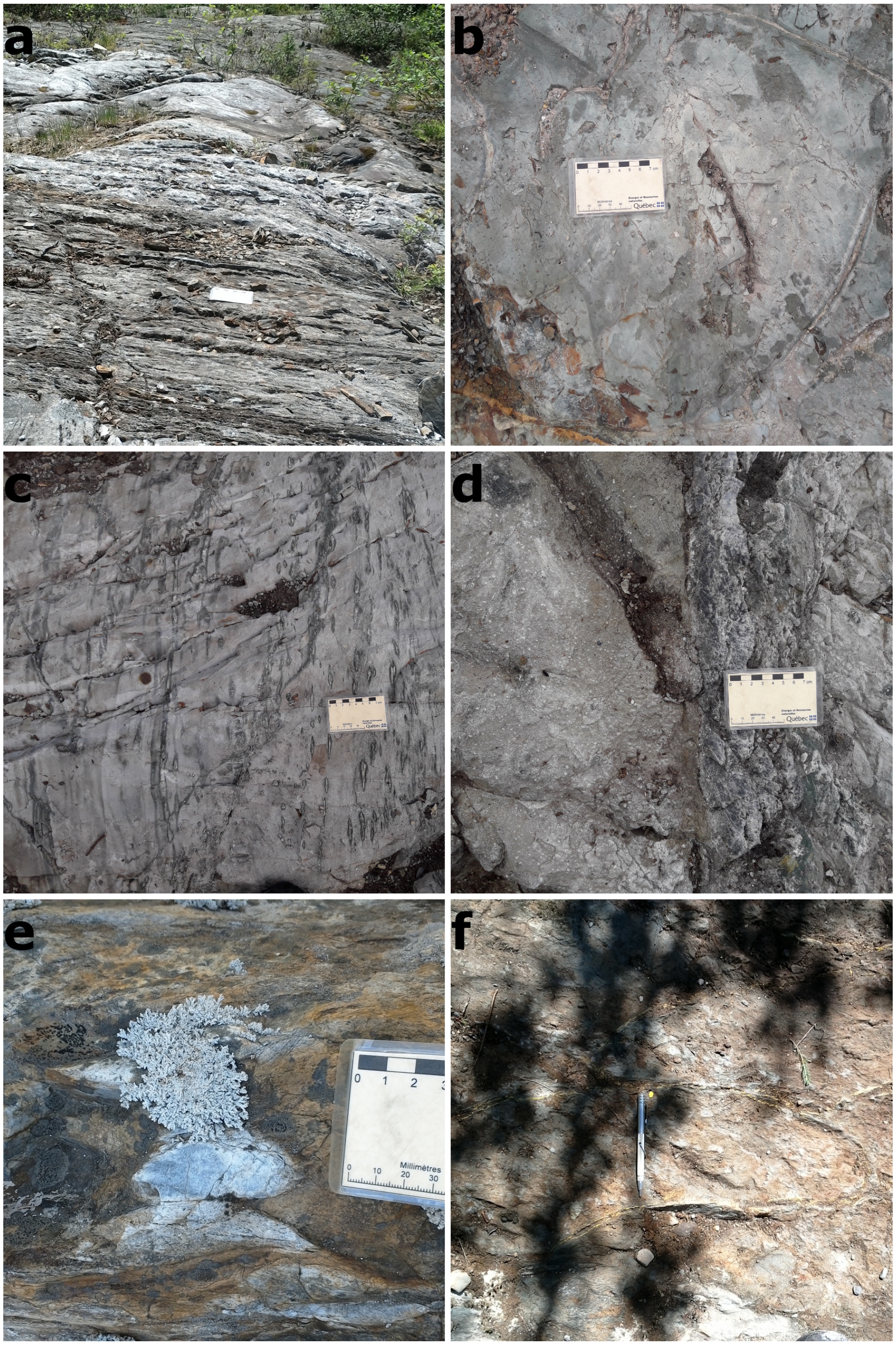

Figure 2. a) Rhyolitic level (light patina in background) hosted in sheared zone basalts of the Obatogamau Formation (no. 1 on Figure 1); card for scale is the same as that used in Figure 2b–e; **b)** Obatogamau Formation pillowed lava containing subcentimetric plagioclase macrocrysts; **c)** monomictic lapilli tuff levels located east of the Muscocho Pluton (no. 2 on Figure 1); **d)** small feldspar crystal-rich mafic level observed on the same outcrop as Figure 2c; a quartz vein marks the contact with lava less-endowed with crystals (at the right of the photo); **e)** example of lapilli contained in the Winchester Member felsic lapilli tuff and block tuff level (no. 3 on Figure 1); **f)** pillowed lava with polarity oriented toward the south (tungsten tip pointing north) located south of the Winchester Member.

Table 1. Résultats de quelques analyses faites à l'aide d'un appareil portatif à fluorescence X (µXRF) de laves mafiques observées à l'est du Pluton de Muscocho (no. 2 sur la figure 1) et de la Formation d'Obatogamau proprement dite (dans la zone cartographiée par transect). Les différences de teneurs en Zr sont à remarquer. Results of some portable X-ray fluorescence spectrometer analyses done on mafic lavas observed east of the Muscocho Pluton (no. 2 on Figure 1) and the Obatogamau Formation as such (in the transect mapping area). The differences in Zn contents should be noted.

Analysis site (internal numbering)	**Si (%)**	**Fe (%)**	**Zr (ppm)**	**Ni (ppm)**
Station 54				
43	22	9	117	72
44	23	9	245	-
45	27	8	255	98
46	25	8	200	100
Transect zone				
47	14	11	33	-
48	21	6	82	96
49	21	8	66	121
50	21	10	23	151
51	22	9	38	128