Origin of the Lac Doré Complex ‘sodagranophyre’ and related mineralizations, Chibougamau Region, Abitibi Subprovince, Quebec

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INTRODUCTION

During summer 2018, as part of the seismic transect mapping campaign of the Metal Earth projet, a study was started on the Lac Doré Complex (CLD) sodium-rich granophyre and the mineralizations it hosts. This report presents an overview of the work completed, the first results achieved and the work planned over the next few months.

This granophyre, termed ‘sodagranophyre’ or sodium-rich granophyre by G.O. Allard in 1976, is equivalent to the felsic granophyric lithological units of the upper portion of the CLD in the heart of the Chibougamau region, at the eastern end of the Abitibi Subprovince. This mafic–ultramafic, deformed and metamorphized synvolcanic layered intrusion is contained within material deposited by the first bimodal volcanic cycle (i.e., transitioning from mafic to felsic) characterisitic of the stratigraphic package in this region. The sodium-rich granophyre might correspond to the upper portion of the magmatic chamber in the CLD, which was in direct contact with the volcanic host rocks and the hydrothermal fluids of the volcanogenic massive sulphide deposits (VMS) that formed around the CLD.

The formation process of the sodium-rich granophyre in the CLD is poorly understood. Some authors interpret it as the product of magmatic differentiation (Alfaro, 1990), whereas others point to a contamination of the magma by the first volcanic cycle rhyolites, in which it is hosted (Daigneault and Allard, 1990). The presence of Cu-Au mineralization as sulphidic quartz-carbonate veins was observed in the sodium-rich granophyre, but these were never studied or documented to identify the depositional setting. Identifying the origin of the sodium-rich granophyre and its relationship to Cu-Au mineralization is a geological problem of some importance to the better understanding of the Chibougamau region.

REGIONAL GEOLOGY

The region of Chibougamau is located at the northeastern end of the Abitibi greenstone belt, bounded to the east by the Grenville Front and to the north by the Opatica Subprovince. Stratigraphy in the Chibougamau area is dominated by two bimodal volcanic cycles that constitute the Roy Group, on which unconformably lie the sedimentary rocks of the Opemisca Group (Figure 1; Norman, 1937; Daigneault and Allard, 1990; Daigneault et al., 1990; Leclerc et al., 2008; Leclerc et al., 2011).

The first volcanic cycle (2730–2726 Ma; Leclerc et al., 2011) has at its base the Obatogamau Formation (Midra, 1989; Leclerc et al., 2008), on which lies the Waconichi Formation (Daigneault and Allard, 1990; Leclerc et al., 2011; Clairet and Gaboury, 2017), whereas the second cycle (2724–2717 Ma; Mortensen, 1993; Leclerc et al., 2011; Davis et al., 2014) consists of the Bruneau, Blondeau and Bordeleau formations (Caty, 1979; Lefebvre, 1991; Leclerc et al., 2008; Bédard et al., 2009; Leclerc et al., 2011).

The Roy Group rocks are cut by large-volume intrusions, such as the CLD (2728–2727 Ma) and the Cummings sills (Daigneault and Allard, 1990; Bédard et al., 2009; Leclerc et al., 2011), and several intermediate–felsic plutons. From 1955 to 2008, the Chibougamau region produced 1.57 Mt Cu, 176.1 t Au, 108.8 t Ag and 0.7 Mt Zn, mainly from Lac Doré-type Cu±Au veins (Pilote and Guha, 2006; Leclerc et al., 2012).

LOCAL GEOLOGY

The sodium-rich granophyre occupies the upper portion of the CLD, where it was observed on both limbs (figure 1; Allard, 1976; Daigneault et Allard, 1990). The 2728.3 +1.2/−1.1 Ma CLD (Mortensen, 1993) is exposed 5–7 km over a distance of 53 km (Daigneault et Allard 1990). It is hosted in rocks of the first volcanic cycle that may have used it as a magmatic chamber (Bédard et al., 2009; Polat et al., 2018). The CLD is the heart of the Chibougamau region as not only has it been the potential thermal driver of VMS-type mineralization, but it also encloses the old Cu-Au central mining camp (Pilote and Guha, 2006; Leclerc et al., 2012) and hosts Fe-Ti-V deposits (Taner et al., 1998; Girard and D'Amour, 2015).

By analogy to other layered intrusions (e.g., Bushveld), the CLD has been divided into three main series (Daigneault and Allard, 1990; Leclerc et al., 2017). The lower zone consists mainly of anorthosite and gabbro-anorthosite and comprises sub-zones with magnetite and peridotite. The layered zone is composed of alternating layers of magnetite ferrogabbro, vadaniferous magnetitite, anorthositic gabbro, dunite, peridotite, pyroxenite and ferrodiorite. The upper portion of the complex consists of a granophyre zone and a discontinuous border zone (Allard, 1976).

The granophyre zone is located above the layered zone (Figure 1). Its upper contact takes two forms (Daigneault et Allard, 1990): in some areas, it is in direct contact with the felsic volcanic rocks of the Waconichi formation, whereas and in other areas, it is in gradual contact with the border zone that separates it from the volcanic rocks. This study focuses on the part of the sodium-rich granophyre that lies close to the seismic transect, where the unit is in contact with volcanic rocks of the Waconichi formation (Figure 1).

THE SODIUM-RICH GRANOPHYRE AND RELATED MINERALIZATION

The term 'sodium-rich granophyre' is used to describe felsic rocks of the CLD due to the granophyric texture of these units, their high Na_2O content (5–6 %) and their low K_2O content (Allard, 1976). It consists of a leucocratic to locally melanocratic tonalite (Alfaro, 1990) consisting of quartz, plagioclase (An_{10}) and chlorite, with traces of epidote, actinote and minor accessory minerals, such as zircon, apatite, magnetite and pyrite (Daigneault and Allard, 1990).

The work during summer 2018 was mainly done in the granophyre band located on the northern limb of the CLD (Figure 1). The aim of this work was to study the contact zone between the sodium-rich granophyre and the rhyolites of the Waconichi Formation, to map and sample the granophyre, and to document the various styles of mineralization it contains to determine the origin of the sodium-rich granophyre and its relation with hydrothermal systems in the Chibougamau region.

The detailed mapping of four strippings in two mineralized sectors (Ramsey et Golden Moon; figure 1) showed that the sodium-rich granophyre does not manifest itself as a band of massive, homogeneous tonalite but rather displays important textural and mineralogical variations.

In the Golden Moon sector, three strippings belonging to the Fieldex Exploration Inc. were studied. Two facies were identified in the granophyre (Figure 2a, b): the coarse-grained facies (Figure 3a), which represents 70% of the stripping surface, is medium- to coarse-grained (1–7 mm) and consists of quartz (60%), feldspar (30%), epidote (3–5%), ankerite (3%), magnetite (2%) and traces of pyrite; 2) the fine-grained facies (Figure 3b), which represents up to 25% of all studied strippings, is fine-grained (1 mm) and consists of feldspar (55%), quartz (30%), epidote (3–8%), ankerite (2–5%), magnetite (1%) and traces of pyrite.

The contact between these two facies is sharp, irregular, sometimes semi-circular or occupied by a zone with modal layering (Figure 3c, d). Small aplite dikes have also been identified (Figure 2b, c); they were observed at the contact between the two facies and their usually rectilinear to slightly undulating shape is at times discontinuous.

The Golden Moon showing (37.7 g/t Au, 73.9 g/t Ag, 2.5 % Cu et 0.03 % Zn; Sansfaçon, 2018) is a vein of smoky quartz, iron carbonate and sulphides 5–20 cm thick and over 20 m long. A sericite-chlorite-ankerite alteration halo >3 m is associated with this vein. The sector is characterized by two abundant families of pegmatitic quartz-carbonate veins locally transitioning to east–west- and north–south-striking quartz-magnétite±pyrite (Figure 3e).

The Ramsey sector is named after a Cu-Au showing (21.94 g/t Au, 171.40 g/t Ag et 6.0 % Cu on 0.50 m; Donovan, 1988) that was mapped in detail (Figure 2d). In one sector, only the coarse-grained facies granophyre was identified. It is cut by east–west-striking gabbro dikes. A porphyritic rhyolite (Figure 2d) over 5 m wide in contact with the sodium-rich granophyre was observed during mapping. It is likely a rhyolite from the Waconichi formation. The contact between the two units is sharp, irregular and locally faulted. A strike of 105°/50° can be inferred at that location from an oriented sample collected in the contact zone.

In this sector, the mineralization corresponds to a sulphide-filled fracture striking 280°/60–75° (Figure 2d). The mineralized zone is approximately 80 m long and 2 cm to 1.5 m thick (Figure 3f). Mineralization mainly consists of massive to semi-massive pyrite with traces of chalcopyrite. A discontinuous, chloritized mafic dyke, with pyrite-mineralized zones occurs in the sulphidic fracture (Figure 2d). Sericite-chlorite alteration forms a halo >2 m in the host. This mineralization is similar to the Cu-Au mineralization styles found at the central mining camp. Both families of pegmatitic quartz-carbonate±pyrite veins have been observed on this stripping.

The work carried out during summer 2018 focused mainly on information gathering on the four mapped strippings, on sampling the main rock units in the study area and on characterizing the various types of mineralization hosted by the sodium-rich granophyre. The dataset collected will be used in laboratory work to be undertaken during the next university sessions.

FUTURE WORK

The main aim of this project is to determine the origin of the CLD sodium-rich granophyre and document the hosted mineralization. This will require additional field mapping, microscope-assisted mineralogical and textural observations, and total rock and in situ sulphide, oxide and quartz analyses. This work will make it possible to determine if the granophyre is the product of partial fusion of the host rhyolites or due to magmatic differentiation within the CLD. This having been determined, the nature of the contact between the CLD and the Waconichi Formation can be documented. The second part of the project aims to determine the relation between the sodium-rich granophyre and central mining camp mineralization.

Consequently, laboratory work over the next two sessions will focus on utilizing the collected petrographic and chemical data. The chemical characteristics of identified mafic dikes will be compared to those of grey dikes at the central mining camp. The geochemical signatures of sampled pyrites will also be compared to those of pyrites from the central mining camp to characterize the geological setting related to the mineral deposit of the study area.

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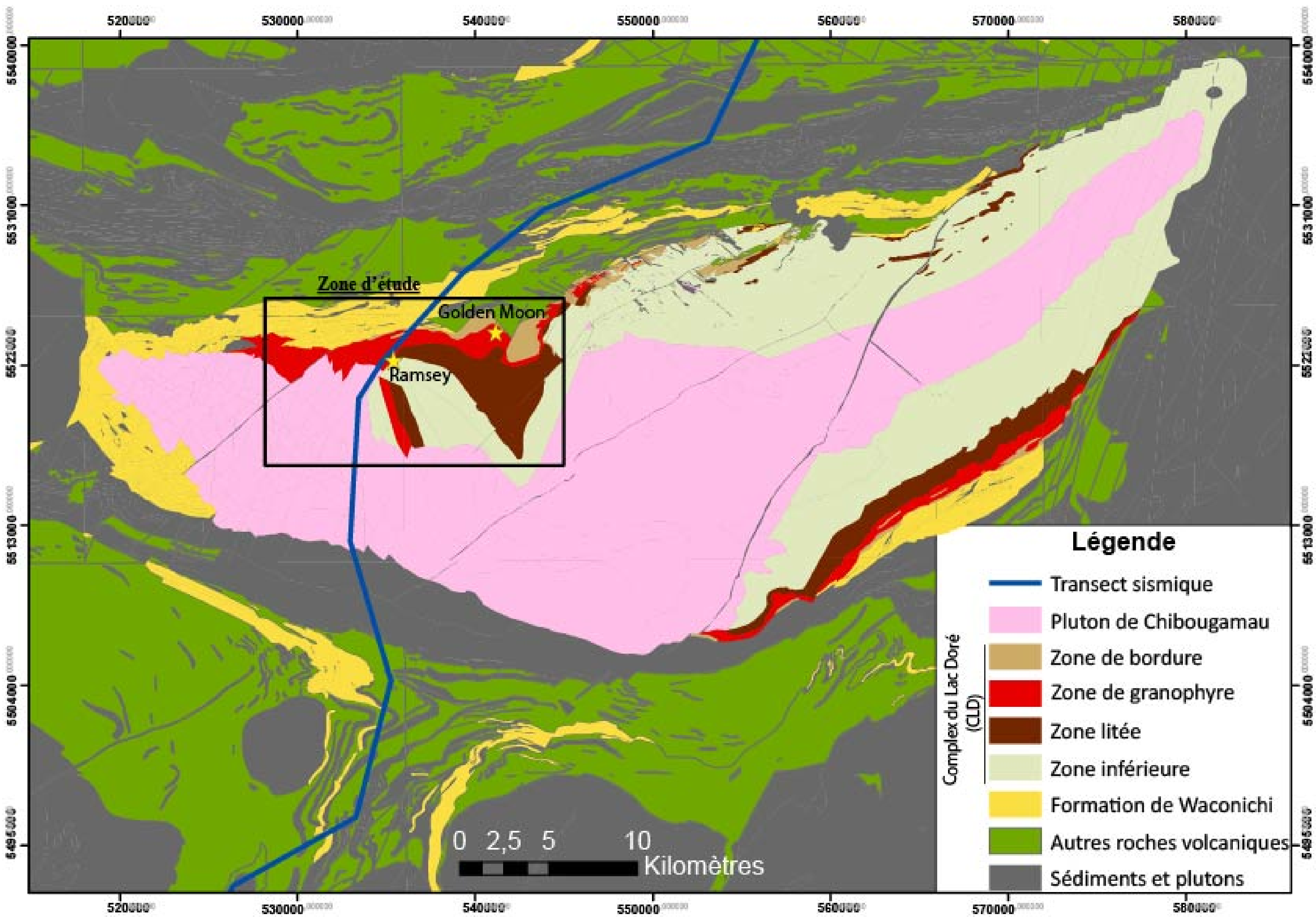

Figure 1. Simplified geology of the Chibougamau area. Figure *modified from* SIGÉOM (SIGÉOM, 2016).

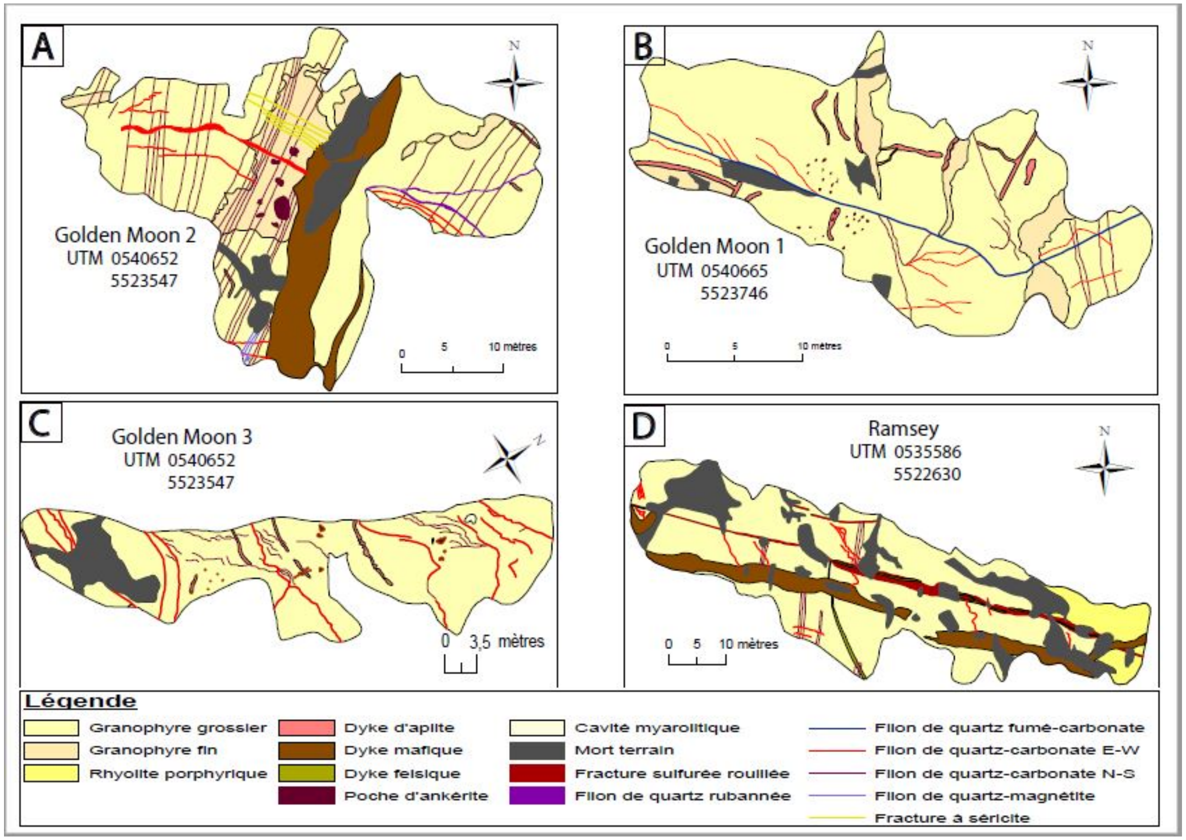

Figure 2. Detailed mapping of the strippings studied during summer 2018 in the Chibougamau area: **a)** Golden Moon stripping No. 2 showing the two granophyre facies cut by a gabbro dike; vein abundance and mineralogical variety should be noted; **b)** Golden Moon stripping No. 1 showing the two granophyre facies and aplite dikes; the gold-bearing quartz vein (in blue) cutting the pegmatitic quartz-carbonate veins should be noted; **c)** Golden Moon stripping No. 3; **d)** Ramsey sector stripping showing the sodium-rich granophyre in contact with porphyritic rhyolite of the Waconichi Formation. The two units are cut by the mineralized structure indicated in red; the mafic dikes within and parallel to the mineralized zone, as well as the two families of pegmatitic quartz-carbonate veins should be noted.

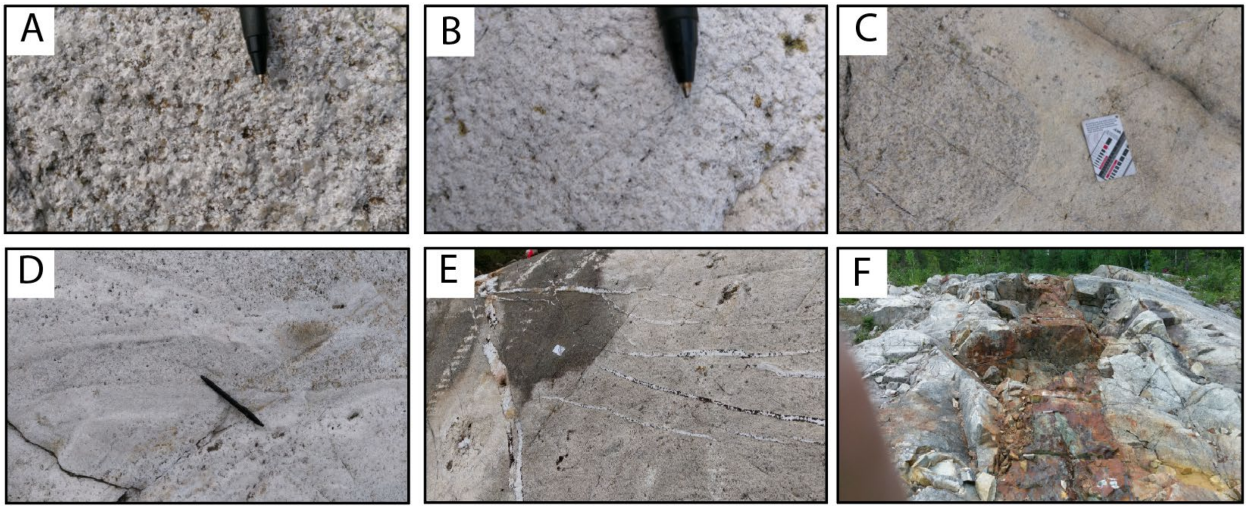

Figure 3. Outcrop photographs of the different sodium-rich granophyre textures and mineralization types in the Golden Moon and Ramsey sectors of the Chibougamau area: **a)** coarse-grained facies of the granophyre (Golden Moon sector); intergrowth between quartz and feldspar grains should be noted: **b)** fine-grained facies of the granophyre (Golden Moon sector); the difference in grain-size and mineralogy to those of the coarse-grained facies should be noted; **c)** contact between the two facies of the granophyre; **d)** modal layering zone at the contact between the two facies of the granophyre; **e)** pegmatitic quartz-carbonate veins; the miarolitic cavity 20 cm wide in the bottom left corner should be noted; **f)** granophyre coarse-grained facies hosted pyrite-chalcopyrite mineralized structure observed on the Ramsey sector stripping.