Spatial Variation of Fluid-Flow Conditions for Orogenic Gold Mineralization in the Augmitto–Bouzan Segment, Abitibi Subprovince, Quebec

G. Raymond[1], B. Quesnel[1], C. Scheffer[1], G. Beaudoin[1], C. Laflamme[1], T.R.C. Jørgensen[2] and B. Chapon[3]

[1]Département de géologie et de génie géologique, Université Laval, Québec, Quebec
[2]Mineral Exploration Research Centre, Harquail School of Earth Sciences, Laurentian University, Sudbury, Ontario
[3]Yorbeau Resources Inc., Montréal, Quebec

INTRODUCTION

Orogenic gold deposits are complex and many key parameters needed for the construction of a well-defined genetic model of these remain unknown or uncertain (Goldfarb et al., 2005). The source of the mineralizing fluid remains a matter of debate as to whether the fluid is released by sediments or hydrated mafic rocks during prograde metamorphism (Beaudoin and Pitre 2005; Goldfarb et al., 2005; Phillips and Powell, 2010; Tomkins, 2013) or whether it is of magmatic-hydrothermal origin (Bath et al., 2013; Tomkins, 2013; Xue et al., 2013; Goldfarb and Groves, 2015). In addition, the cause(s) of gold precipitation is(are) not clearly understood, as is evident from the different mechanisms proposed in the literature. Gold precipitation facilitated by pressure decrease related to the fault-valve model (Sibson et al., 1988; Robert et al., 1995), fluid-rock reaction (Evans et al., 2006), boiling (Weatherley and Henley, 2013), fluid mixing (Bateman and Hagemann, 2004; Beaudoin and Pitre, 2005; Beaudoin and Chiaradia, 2016) and chemisorption on surfaces of pyrite and arsenopyrite (e.g., Möller and Kersten, 1994) are some of the mechanisms that have been proposed.

A comparison of the stable-isotope signatures ($\delta_{18}O$, δD and $\delta_{13}C$) of hydrothermal fluids that circulated in the 12 km long Augmitto–Bouzan segment of the Cadillac–Larder Lake deformation zone (CLLDZ; Figure 1) is presented in this study. This segment is characterized by significant but erratically distributed gold-enriched zones. The main goal of this project is to determine if the spatial variation of fluid-circulation conditions could help explain the discontinuous distribution of gold mineralization. First, focus will be on the identification of the source(s) of the mineralizing fluid and the possible involvement of fluid mixing along the segment. Secondly, the spatial variation of the fluid flow and related fluid–rock interaction will be constrained. To achieve the research goals, the 2019 field season involved sampling of multiple veins and hostrocks from drillcores and outcrops along the Augmitto–Bouzan segment on the Rouyn-Noranda property of Yorbeau Resources Inc.

REGIONAL GEOLOGY

The Neoarchean Abitibi Subprovince is composed of east-trending sequences of volcanic and sedimentary rocks, crosscut by multiple intrusive rocks (Monecke et al., 2017). It spans across the Quebec–Ontario border and represents the southeastern part of the Superior Province (Monecke et al., 2017).

The Rouyn-Noranda region of the Abitibi greenstone belt is composed of ultramafic and mafic rocks of the ca. 2709.5–2705.9 Ma Piché group (Latulippe, 1976; Simard et al., 2013, Pilote et al., 2015; Bedeaux et al., 2018), volcanic rocks of the ca. 2704–2695 Ma Blake River group (Corfu et al., 1989;

Corfu, 1993; Mortensen, 1993; Ayer et al., 2002; Lafrance et al., 2005; David et al., 2006; Thurston et al., 2008; Ross et al., 2011), turbiditic units of the ca. 2685–2682 Ma Pontiac group, from the Pontiac Subprovince (Goulet, 1978; Dimroth et al., 1982; Mortensen, 1993; Davis, 2002; Bedeaux et al., 2017; Frieman et al., 2017), and sedimentary rocks of the ca. 2680–2670 Ma Granada and La Bruyère formations belonging to the molasse-type basin of the Timiskaming Group (Mueller et al., 1994; Salmon and McDonough, 2011; Frieman et al., 2017). The rocks also display relics of at least three post-Timiskaming deformation events, of which the main event is an early north–south shortening event (Bedeaux et al., 2017). A regional metamorphic event has affected the supracrustal rocks between 2677 and 2643 Ma, and ranges in grade from the subgreenschist to the greenschist-to-amphibolite transitional facies (Powell et al., 1995).

The Cadillac–Larder Lake deformation zone is a 250 km long, east-trending and subvertical, crustal-scale first-order fault, which is recognized as an important host for gold mineralization in the Abitibi (Gunning and Ambrose, 1940; Norman, 1946; Card, 1990; Powell, 1992; Daigneault et al., 2002; Rabeau et al.,2010; Bedeaux et al., 2017, 2018). Development of the fault system allowed gold-bearing hydrothermal fluids to circulate and led to the precipitation of gold along smaller scale subsidiary structures, which resulted in the formation of orogenic gold deposits (Rabeau et al., 2010; Bedeaux et al., 2017). The main gold mineralization episodes of the region are bracketed between 2680 and 2670 Ma, and have been associated with the main shortening event and a late strike-slip event (Robert, 1989; Kerrich and Kyser, 1994; Neumayr et al., 2000; Goldfarb et al., 2001; Robert et al., 2005; Lafrance, 2015; Bedeaux et al., 2017). Other gold-bearing deposits can also be found in the vicinity of the CLLDZ, such as volcanogenic massive sulphide, and replacement-type and intrusion-related gold deposits (Couture and Pilote, 1993; Couture, 1996; Couture and Willoughby, 1996; Legault and Rabeau, 2007; Mériaud and Jébrak, 2017).

LOCAL GEOLOGY

The Augmitto–Bouzan property of Yorbeau Resources Inc. covers 12 km along the CLLDZ in the Rouyn-Noranda region and is divided into multiple blocks. The submarine and mostly mafic units of the Blake River group cover the northern part of the property and the metawacke of the Pontiac group dominates the southern part (Ross et al., 2011; Camiré et al., 1993). The conglomerate, sandstone and siltstone of the Timiskaming Group overlie those groups. The La Bruyère and Granada formations are part of the Timiskaming Group and are located north and south of the CLLDZ, respectively (Salmon and McDonough, 2011). The carbonatized and schistose-textured ultramafic rocks of the Piché group are found within the two formations mentioned previously and are spatially related to the CLLDZ (Salmon and McDonough, 2011; Bedeaux et al., 2017). Indeed, the talc and chlorite schists of the Piché group are interpreted as the physical expression of the deformation zone (Dimroth et al., 1982; Bedeaux et al., 2018). The main target for gold mineralization is hosted by quartz veins in the Piché group, especially the lower Piché subzone, but is also found within albitic dykes located in the same group or in contact with the Timiskaming sediments (Salmon and McDonough, 2011).

Gold content changes laterally from the endowed western blocks (Augmitto to Astoria: Figure 2) to the less-endowed eastern blocks (East-Bay and Bouzan; Figure 3). Field and core observations show significant differences between these areas; for example, the thickness of Piché group ultramafic rocks decreases toward the Bouzan segment and the La Bruyère formation of the Timiskaming Group altogether disappears.

FIELDWORK

The 2019 summer fieldwork was carried out along the Augmitto, Cinderella, Lac Gamble, Astoria, East-Bay and Bouzan blocks (Figure 1). Sampling was carried out in the area that Yorbeau Resources Inc.

geologists refer to as the 'main zone'. It is defined as an area with favorable carbonate±fuchsite alteration that locally contains high gold grades ranging from 5 to >25 g/t/m (Figures 2, 3) and is located close to the southern Piché–Timiskaming contact. The boreholes were selected to obtain a regular grid along the property, laterally and vertically, as well as to present an even distribution between endowed and less-endowed zones within the main zone (Figures 1–3). A total of 45 boreholes distributed among the different blocks of the property were selected for sampling. Every vein encountered has been thoroughly described and the crosscutting relationships have been noted to produce a paragenetic sequence for each block, which allows vein families related to the gold mineralization events to be identified. Systematic sampling of each vein type and representative hostrock resulted in the collection of 354 samples.

FUTURE WORK

Oxygen isotopes in quartz, tourmaline, chlorite, carbonate and hostrock samples will be analyzed for their $\delta_{18}O$ values and results are expected in early 2020. Data will be processed and georeferenced to build a cross-section showing the spatial variations in $\delta_{18}O$ values and provide insights into the hydrothermal-fluid circulation along the Augmitto–Bouzan segment.

The reactive-transport model of Beaudoin et al. (2006) will be applied to investigate the interaction between hydrothermal fluid and hostrocks along the segment. Furthermore, the kinetics of oxygen isotope exchange between the circulating fluid(s) and the hostrocks will be modeled. Based on this model, the nature of the fluid-flow pattern required to reproduce the spatial variation of oxygen isotope compositions of documented fluids will be determined. Finally, this pattern will be compared with the spatial distribution of endowed and less-endowed areas along the Augmitto–Bouzan segment.

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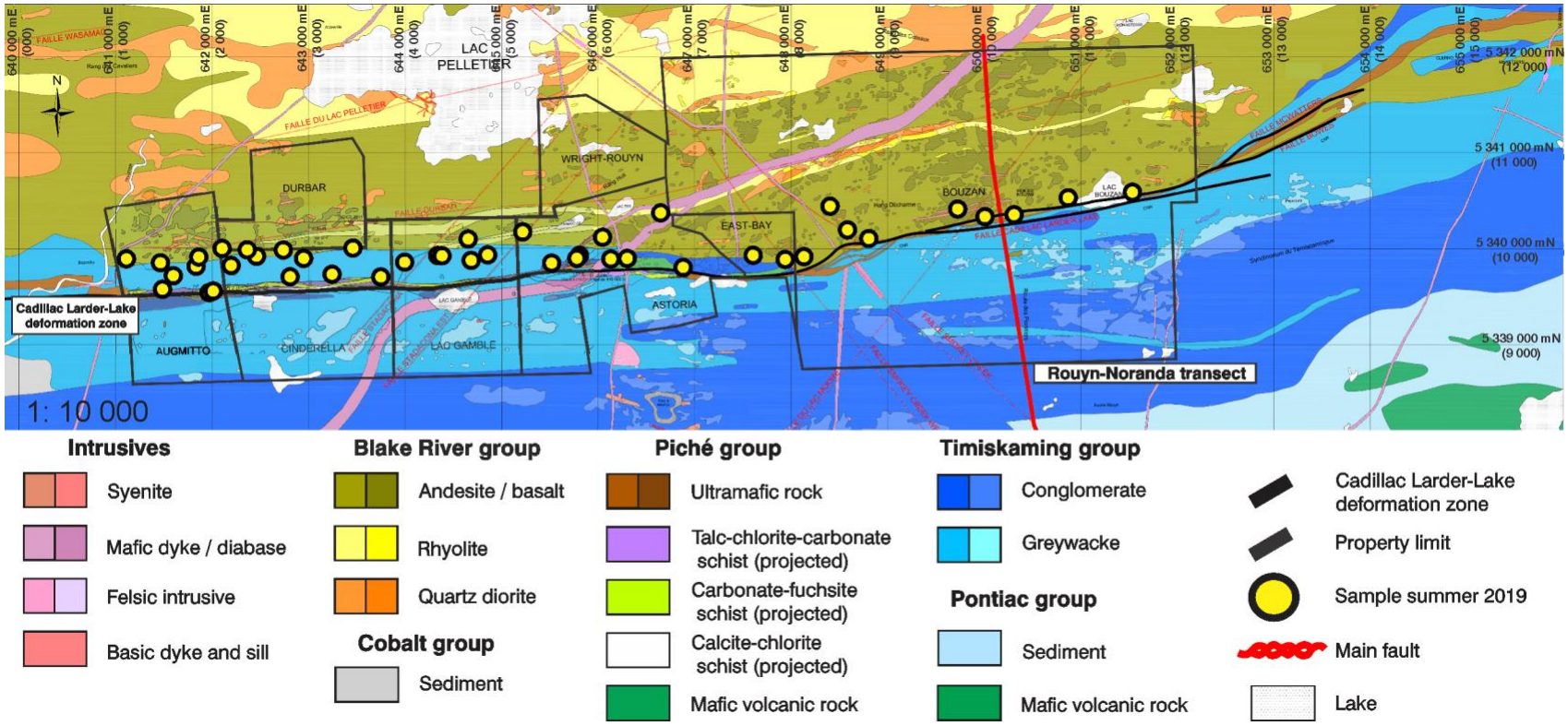

Figure 1. Regional geology of the Rouyn property of Yorbeau Resources Inc., with the sampled boreholes indicated by the yellow circles (*modified from* Wilson, 1962). Source: D. Gravel, B. Chapon and L. Hallé (unpub. data, 2017). Universal Transverse Mercator (UTM) coordinates are in North American Datum 1983 (NAD83), Zone 17N.

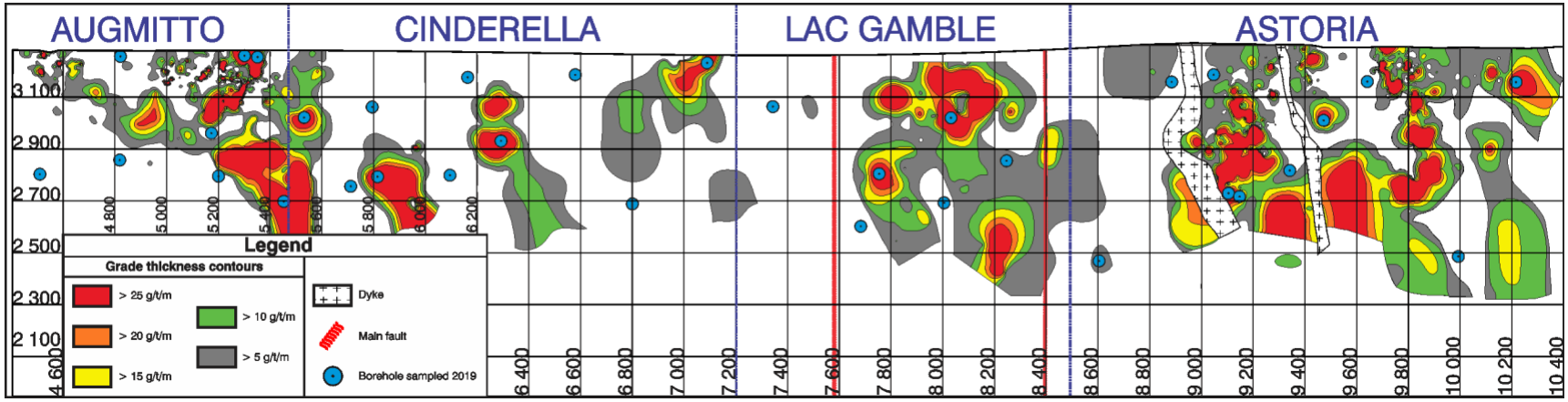

Figure 2. Longitudinal section along the main zone of the endowed part of the Rouyn property of Yorbeau Resources Inc. presenting grade-thickness values, with the sampled boreholes indicated by blue circles. Source: D. Gravel, B. Chapon and L. Hallé (unpub. data, 2015). Modified Transverse Mercator (MTM) coordinates are in North American Datum 1983 (NAD83), Zone 10.

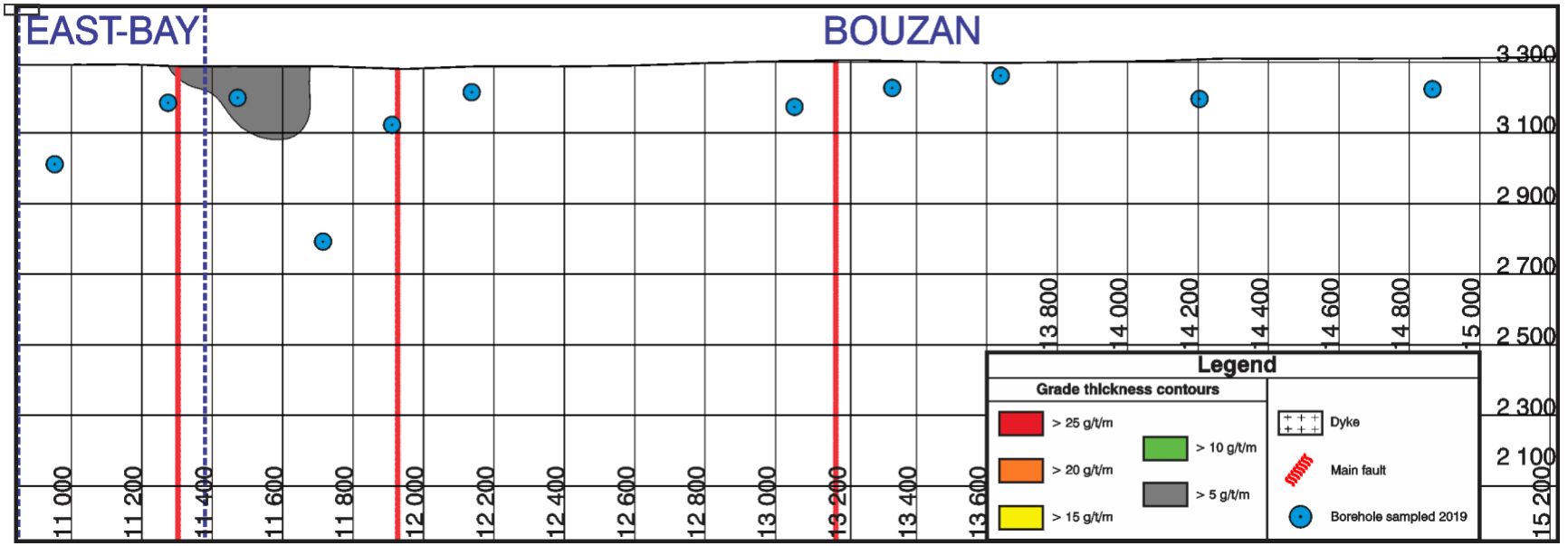

Figure 3. Longitudinal section along the main zone of the less-endowed part of the Rouyn property of Yorbeau Resources Inc. presenting grade-thickness values, with the sampled boreholes indicated by blue circles. Source: D. Gravel, B. Chapon and L. Hallé (unpub. data, 2015). Modified Transverse Mercator (MTM) coordinates are in North American Datum 1983 (NAD83), Zone 10.