Re-examination of the Joliet Breccia, Rouyn-Noranda, Quebec

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INTRODUCTION

The results presented herein represent fieldwork completed in 2019 as part of a four-year Ph.D. project conducted by the lead author within the Powell block, along the Metal Earth Rouyn-Noranda transect. The Metal Earth research initiative is conducted by the Mineral Exploration Research Centre at Laurentian University (Sudbury, Ontario). The overall goal of this research project is to characterize the base (Cu, Zn)- and precious (Au)-metal mineral occurrences and deposits within the Powell block and place them within a time-stratigraphic and deformational context. This will be achieved by 1) compiling and building on existing maps of the Powell block area (H.R. Morris, unpub. data 1957, 1959) and 2) undertaking new detailed geological mapping at the 1:500 scale of important stratigraphic markers, structural features and/or mineralized zones, supplemented with stratigraphic transects within adjacent fault blocks, lithogeochemical analyses and sampling for high-precision U-Pb isotopic geochronology.

The focus of this report is the Joliet breccia, which is characterized by intense chlorite, sericite and spotted alteration, and which has been observed to be associated with base-metal mineralization elsewhere in the district (de Rosen-Spence, 1969; Fitchett, 2012; Schofield et al., 2018). The Joliet breccia exhibits similarities to unusual breccia pipes in the Noranda camp (e.g., St. Jude, Chadbourne and Newbec breccias) of uncertain origin (Wilson, 1941; de Rosen-Spence, 1976; Dimroth and Rocheleau, 1979; Lichtblau and Dimroth, 1980; Walker and Cregheur, 1982; Smith, 1983; Galley and van Breemen, 2002).

REGIONAL GEOLOGY

The ca. 2704–2695 Ma Blake River group (BRG) of the southern Abitibi greenstone belt, comprises a bimodal submarine volcanic succession 12 000–15 000 m thick that is bounded to the north by the Porcupine–Destor fault system and to the south by the Larder Lake–Cadillac fault system (Baragar, 1968; Goodwin and Ridler, 1970; McNicoll et al., 2014). The Noranda mining camp marks a distinct volcanic centre within the BRG, characterized by the thickening of volcanic successions, an increased proportion of felsic volcanic rocks, and the presence of synvolcanic intrusions (e.g., Flavrian and Powell intrusive complex) and associated synvolcanic faults (Spence and de Rosen-Spence, 1975; Gibson and Watkinson, 1990; McNicoll et al., 2014). The hostrocks of the Noranda camp consist of a conformable sequence, roughly 6000 m thick, of predominantly andesite and rhyolite of the ca. 2701–2696 Ma upper Blake River group (Spence and de Rosen-Spence, 1975; de Rosen-Spence, 1976; Gélinas et al., 1984; Ayer et al., 2005). Volcanic products are predominantly effusive flows, with minor pyroclastic deposits marked locally by bedded tuff and lenses of coarse breccia occurring proximal to interpreted eruptive centres (Spence and de Rosen-Spence, 1975). Strata of the Noranda camp are offset by numerous east-northeast-striking faults and divided into several fault blocks, including the Flavrian block, the Powell block and the Horne block (Figure 1).

PREVIOUS WORK ON THE JOLIET BRECCIA

The Joliet breccia is an historical Cu mineral occurrence staked by a team of prospectors led by J.A. Brownlee in 1922 and subsequently described by M.E. Wilson (1941). The Joliet breccia was mapped in detail by de Rosen-Spence (1976), Lichtblau and Dimroth (1980), who assigned the name 'Joliet Breccia', and H.R. Morris (unpub. data, 1959). Re-examination of the Joliet breccia was deemed critical for this study, as its origin and timing has metallogenic significance: the crosscutting relationships constrain the age of the Cu-Zn mineralization and associated alteration within the breccia, which might relate to a similar style of mineralization and alteration observed throughout the Powell block (Figure 2).

The Joliet breccia is hosted by the Quemont feeder dyke, which marks a stratigraphic discontinuity defined by the termination of a mafic-dominated volcanic succession to the north and commencement of a thick succession of felsic flows and volcaniclastic rocks to the south (Figure 1). Correlation across the Quemont feeder dyke has been contentious. Nevertheless, it is apparent that this dyke occupies a major structure in the Powell block, with the current Quemont feeder dyke only representing the most recent intrusive phase along this structure.

The present interpretation for the Joliet breccia is that it is a steam-explosion breccia, related to the emplacement of the Quemont feeder dyke, and that it is likely of similar origin to the Quemont breccia south of the dyke (de Rosen-Spence, 1976; Dimroth and Rocheleau, 1979; Lichtblau and Dimroth, 1980; Lichtblau, 1989). Lichtblau and Dimroth (1980) and Lichtblau (1989) explained the current map pattern by breccia falling back into a crater; their interpretation would make the Joliet breccia synvolcanic. Alternatively, the Joliet breccia could be related to a younger event similar in style to the St. Jude, Chadbourne and Newbec breccias (Wilson, 1941; Walker and Cregheur., 1982; Smith, 1983).

The St. Jude, Chadbourne and Newbec breccias are relatively young, pipe-like breccia bodies that crosscut volcanic stratigraphy at a high angle. The St. Jude breccia contains Cu-Mo-Au mineralization and is constrained to ca. 2697 Ma, based on ages returned from crosscutting quartz-porphyritic aplite dykes (Galley and van Breemen, 2002). The Chadbourne breccia was interpreted as post-Timiskaming because it crosscuts a north–south syenite dyke. In addition, the structural reconstruction by Walker and Cregheur (1982) showed the breccia as crosscutting previously tilted and steeply dipping volcanic rocks. The Chadbourne breccia produced approximately 1.4 Mt grading 3.65 g/t Au. It consists of subangular, rectangular to lath-shaped clasts of predominantly andesite, ranging in size from 2 cm to 1.5 m in length, in a matrix of quartz, albite, ankerite and dolomite with accessory pyrite, specularite and tourmaline (Walker and Cregheur, 1982); the Chadbourne breccia body has a gradational contact with the host andesite. The Newbec breccia is interpreted as pre-Timiskaming because it is crosscut by the ca. 2690 Ma (Mortensen, 1993) Lac Dufault intrusion (Smith, 1983). The Newbec breccia consists of tabular-shaped fragments of rhyolite, quartz-feldspar porphyry, andesite, quartz diorite, tuff and gabbro in a matrix of altered quartz-feldspar porphyry consisting of fine-grained chlorite, quartz, ankerite, pyrite and molybdenite (Wilson, 1941). Wilson (1941) noted similarities between the Newbec breccia and the Chadbourne breccia, and inferred that they likely formed in the same way.

The northern Joliet breccia mineral occurrence consists of disseminated and fracture-controlled pyrite and chalcopyrite±quartz in a chloritized rhyolite breccia, whereas the southern occurrence consists of fracture-controlled pyrite and chalcopyrite ± quartz within the Joliet rhyolite. Although prospected, trenched and drilled, the northern Joliet breccia mineral occurrence was not mined. The Joliet orebody was discovered under cover 200 m east of the southern occurrence and, based on the ore outline displayed on historical company maps, at 100 m and 200 m depths, the orebody had a pipe-like shape with a diameter of 50 m and a long axis plunging moderately southward. The Joliet orebody produced 1 465 403 t averaging 0.905% Cu, as siliceous flux copper ore (Sabina, 2003). It is interpreted as discordant volcanogenic massive sulphide (VMS) stringer or stockwork mineralization (Monecke et al., 2017). The only known VMS deposit in the area is the Quemont deposit, which had an average grade of 1.3% Cu and 5.5 g/t Au.

GEOLOGY OF THE JOLIET BRECCIA

Hostrocks

The Quemont feeder dyke is a leucocratic, quartz-phyric felsic dyke with 5–10% euhedral quartz phenocrysts, varying in size from 0.5–1 mm, in an aphanitic matrix. The dyke strikes east to northeast (070°), dips steeply toward the north (~85°) and has a sharp, but irregular contact with the rocks to the north. The southern contact with felsic volcaniclastic rocks of the Joliet rhyolite is sharp, where observed west of the Joliet orebody. Abundant, fine-grained and commonly quartz-phyric xenoliths (~0.5 –30 cm in diameter) found toward the margins of the dyke are chloritized, weather dark brown green, have a green fresh surface and locally contain ~5% quartz-phenocrysts averaging 1 mm or less in diameter (Figure 3a). These xenoliths exhibit irregular scalloped margins.

The rocks located immediately north of the Quemont feeder dyke are massive, coherent, amygdaloidal aphanitic mafic units, interbedded with a polymictic lapilli tuff of the upper marker horizon (Lichtblau, 1989). The mafic units are crosscut by numerous aphyric rhyolite dykes that strike east to east-northeast and appear to be boudinaged. The upper marker horizon contains felsic to intermediate leucocratic fragments, ranging in diameter on average from 2 to 5 mm and reaching up to approximately 0.3 to 0.5 m, that have rounded irregular margins. They appear to be randomly distributed, with no evidence for stratification.

The first appearance of clear volcanic flow features occurs north of the Powell fault (Figure 2). Here, strata strike north-northwest, dip steeply to the east and consist of pillowed to massive mafic flows of the Powell andesite, interbedded with mafic volcaniclastic rocks, which are overlain by thinly laminated bedded tuff and a quartz-phyric rhyolite tuff breccia. The gradation from mafic volcanic flows to overlying mafic breccia, as well as the asymmetry of infill sedimentation in the rhyolite tuff breccia, suggests younging toward the east.

The hostrocks south of the Quemont feeder dyke consist of aphyric lobe-hyaloclastite rhyolite, historically referred to as the ‘Joliet rhyolite’ (de Rosen-Spence, 1976). The Joliet rhyolite is interbedded with polymictic volcaniclastic units, which consist of dominantly aphyric rhyolite clasts (~70%), and minor quartz-phyric felsic (~10%) and mafic clasts (~20%), ranging from lapilli tuff to tuff breccia. The volcaniclastic rocks are crudely bedded, with minor variations in clast sizes and abundances. Crosscutting the volcaniclastic units are numerous quartz-phyric (quartz phenocrysts ~1 mm in diameter, 5–10% abundance), flow-banded sills/dykes with sharp contacts. Overlying the Joliet rhyolite is the Quemont rhyolite, which is a quartz-phyric (quartz phenocrysts ~1 mm in diameter, 10% abundance) lobe-hyaloclastite rhyolite. The Quemont rhyolite is also interbedded with crudely bedded, polymictic volcaniclastic rocks, which consist of dominantly quartz-phyric clasts (~60%), aphyric rhyolite clasts (~25%) and mafic clasts (~15%).

Joliet Breccia

The Joliet breccia is hosted within the Quemont feeder dyke and adjacent massive aphanitic and feldspar-phyric mafic units, where it constitutes an approximately 250 m (E–W) by 150 m (N–S) breccia body that has a crude, elliptical form in plan view. Based on the distribution and composition of clasts, the breccia body is subdivided into three domains: a felsic-dominated domain, a transitional domain and a mafic-dominated domain. The boundaries between these domains are gradational and approximate. In addition, the boundary between the Quemont feeder dyke and the felsic-dominated domain is gradational.

This contact was defined as the transition from an outer, localized fracture zone, to the first appearance of fractures/breccia with open void space (typically ≤10% void space). The appearance of over 10% void space defines an in situ shattered zone, where clasts have an intact jigsaw-fit pattern, with virtually no rotation (Figure 3b). This monomictic, in situ shattered zone defines the felsic-dominated domain, which contains >70% quartz-phyric felsic clasts, 1 to 70 cm in size, and local blocks 2 to 3 m in size, which have the same abundance and size of quartz phenocrysts as the Quemont feeder dyke, and <30% matrix. The breccia is clast supported with very little interstitial matrix of fine-grained green chlorite (Figure 3b, c), at times containing vuggy quartz±sulphides (chalcopyrite and pyrite; Figure 3d). In general, the matrix chlorite does not appear to represent distinct mafic clasts (Figure 3b, c). The quartz-phyric rhyolite fragments are angular and rectangular to lath-shaped with curviplanar margins (Figure 3b). The long axis of the fragments is parallel to the southern contact with the Quemont feeder dyke and the internal contacts, with the transitional domain.

The transitional domain is a polymictic breccia with 50 to 70% chloritized mafic clasts, 5–14 cm in size and ≤50% quartz-phyric rhyolite clasts, and marks the first evidence of minor clast rotation. In this domain, the chloritized zones define distinctive angular 'mafic' fragments (Figure 3e), which are variably spotted, as well as interstitial chlorite. The shapes and sizes of the quartz-phyric rhyolite clasts are identical to those within the felsic-dominated domain. The transitional domain occurs as lenses within the felsic-dominated and mafic-dominated domains, with the contacts paralleling the outer contact of the Joliet breccia.

The mafic-dominated domain consists of >70% mafic clasts (Figure 3f) and represents a poorly sorted polymictic breccia, with fragments ranging in size from 3 to 60 cm and local blocks 2 m or more in diameter. The breccia is clast supported, with ≤10% matrix material. Interfragment space is infilled by an outer margin of coarse, vuggy quartz (grains ~3–5 mm long) and an interior of fine-grained chlorite and sulphides (fine-grained chalcopyrite and pyrite). The clasts consist of quartz-phyric rhyolite, aphyric–aphanitic rhyolite, aphanitic to fine-grained massive mafic rocks, medium-grained tonalite, amygdaloidal (10% at 0.5–5 cm diameter amygdules) mafic rocks, as well as blocks of finely bedded mafic tuff. This unit is in sharp contact with a granitoid body, which was previously interpreted as being younger and intruding the breccia (Dimroth and Rocheleau, 1979).

The granitoid is medium grained and equigranular to porphyritic (Figure 3g), containing ~55% feldspar and ~45% quartz, and is interpreted as a tonalite. The grain size of the tonalite does not become finer in proximity to the mafic-dominated domain, which also contains blocks of the tonalite.

Structural Geology

The principal east-west, steeply dipping foliation overprints the Joliet breccia with similar orientations measured in the matrix and in the clasts, although the foliation is more strongly developed in the chloritized matrix. The fractured outer stockwork zone that surrounds the breccia within the Quemont feeder dyke was more strongly developed on the eastern to southeastern side and is virtually absent along the western side. The fractures display two preferred orientations northeast to east-northeast (typically 30°–60°) and northwest to north-northwest (typically 330°–350°). This fracture pattern persists northward to the Powell fault; however, near the fault, the fractures have a northeast (~60°) and east-southeast (~100°) orientation.

Alteration

The main alteration minerals are chlorite and sericite, and the abundance of these minerals appears to intensify with increasing degree of brecciation (and clast rotation). The outer stockwork zone within the Quemont feeder dyke consists of fractures, variably infilled by quartz±sulphides, bordered by a spotted leucocratic alteration halo (typically 1–8 cm in width); this infill tends to be more resistant to weathering than the outer, least altered rhyolite. This style of alteration is also observed rimming the larger felsic clasts within the breccia (Figure 3b, h) and pervasively altering the smaller fragments within the in situ shattered zone (Figure 3b). Chlorite occurs as matrix material (Figure 3b, c) ±quartz±sulphides, and as a metasomatic alteration of mafic clasts. Chlorite has completely replaced the mafic blocks within the transitional domain as well as the smaller blocks of the mafic-dominated domain and occurs as an alteration rim around larger mafic blocks within the mafic-dominated domain. Spotted alteration is variably developed within the mafic blocks, with some blocks composed entirely of massive chlorite with no visible spots, in contrast to other blocks that have a spotted rim and a chlorite core (Figure 3i), or a spotted core with a chlorite rim (Figure 3j).

Mineralization

Mineralization consists of fine-grained sulphides (dominantly fine-grained pyrite and chalcopyrite) that generally occur within the vuggy matrix that is interstitial to fragments. However, a northeast-striking sulphide vein approximately 1 cm wide was observed crosscutting the breccia. In addition, thin sulphide veinlets were observed crosscutting the chloritized rim of mafic clasts. The degree of sulphide mineralization varies, with the strongest mineralization occurring within the core of the mafic-dominated breccia domain (~10–15%; Figure 3f, h), weak to intermediate amounts within the transitional breccia domains (~5–10%; Figure 3e) and local weak to intermediate amounts within the felsic-dominated domain (<5%; Figure 3d) spatially associated with chlorite. Fine-grained disseminated pyrite was also observed within the tonalite. Sulphides are also present within fractures of the outer stockwork zone and as crosscutting fractures within the tonalite.

CONCLUSIONS

The Joliet breccia consists of disseminated to fracture-controlled low-grade Cu-Zn mineralization within a breccia body. There are six other Cu-Zn mineral occurrences in the Powell block (Figure 2) that consist of high-grade veins, which occur along synvolcanic faults and are interpreted as the plumbing system of a VMS deposit. Despite differences in morphology and grade, the Joliet breccia exhibits similar mineralogy, metal proportions and alteration to these other mineral occurrences and therefore may or may not be a part of this system. Therefore, increased knowledge on the Joliet breccia will help in better understanding the evolution of the hydrothermal system with respect to the host volcanic strata, which in turn could aid in delineating and targeting horizons most likely to host massive sulphide lenses.

Clasts of tonalite within the Joliet breccia indicate that brecciation took place during, or continued after, emplacement of the tonalite. The field observations demonstrate the late paragenesis of the copper sulphide mineralization and related alteration with respect to the formation of both the tonalite and the Quemont feeder dyke. A sample of the tonalite has been submitted for U-Pb zircon geochronology (Figure 2), the results of which will provide some constraints on the timing of mineralization. In addition, the overprinting cleavage, and asymmetric distribution of fractures surrounding the breccia suggest that it was emplaced prior to regional deformation.

FUTURE WORK

Future work conducted over the fall and winter months will focus on petrography and geochemistry of the Joliet breccia, as well as other mineral occurrences sampled this past field season. The samples collected along two transects across the Joliet breccia were sent for whole-rock analysis at ALS Geochemistry (Sudbury, Ontario) and that data will be used to look at metal zonation within the breccia. This data will be supplemented by detailed petrography to characterize both the mineralization and alteration, and document any unique textural features within the breccia that might aid in interpreting the origin of the breccia.

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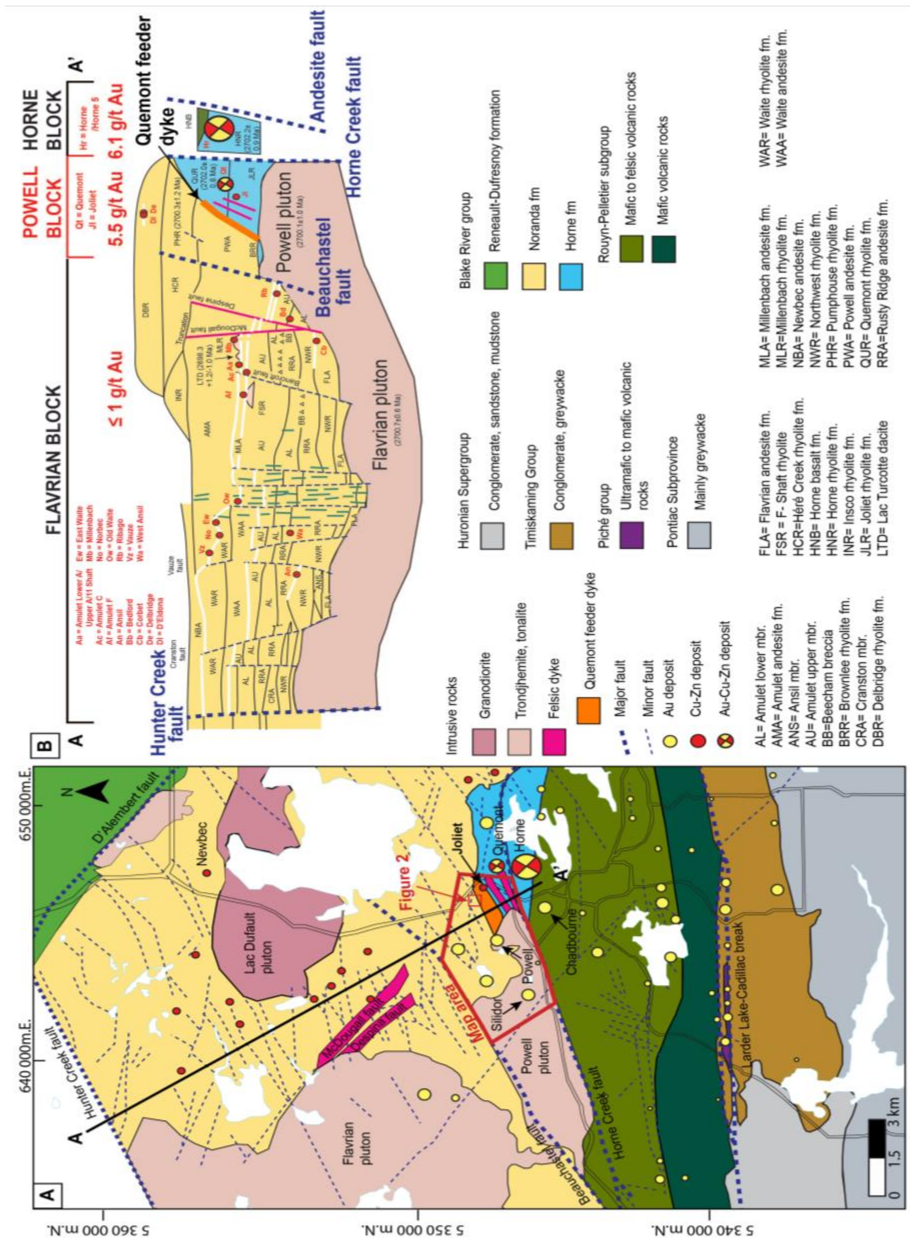

Figure 1. A) Regional geology of the Rouyn-Noranda mining camp, showing the distribution of mineral occurrences (*modified from* McNicoll et al., 2014, and Poulsen, 2017). Project area outlined by the red box. **B)** Cross-section along line A-A' from Figure 1A, showing the existing stratigraphy and correlations within the Rouyn-Noranda mining camp (*modified from* Gibson and Watkinson, 1990, and Monecke et al., 2017).

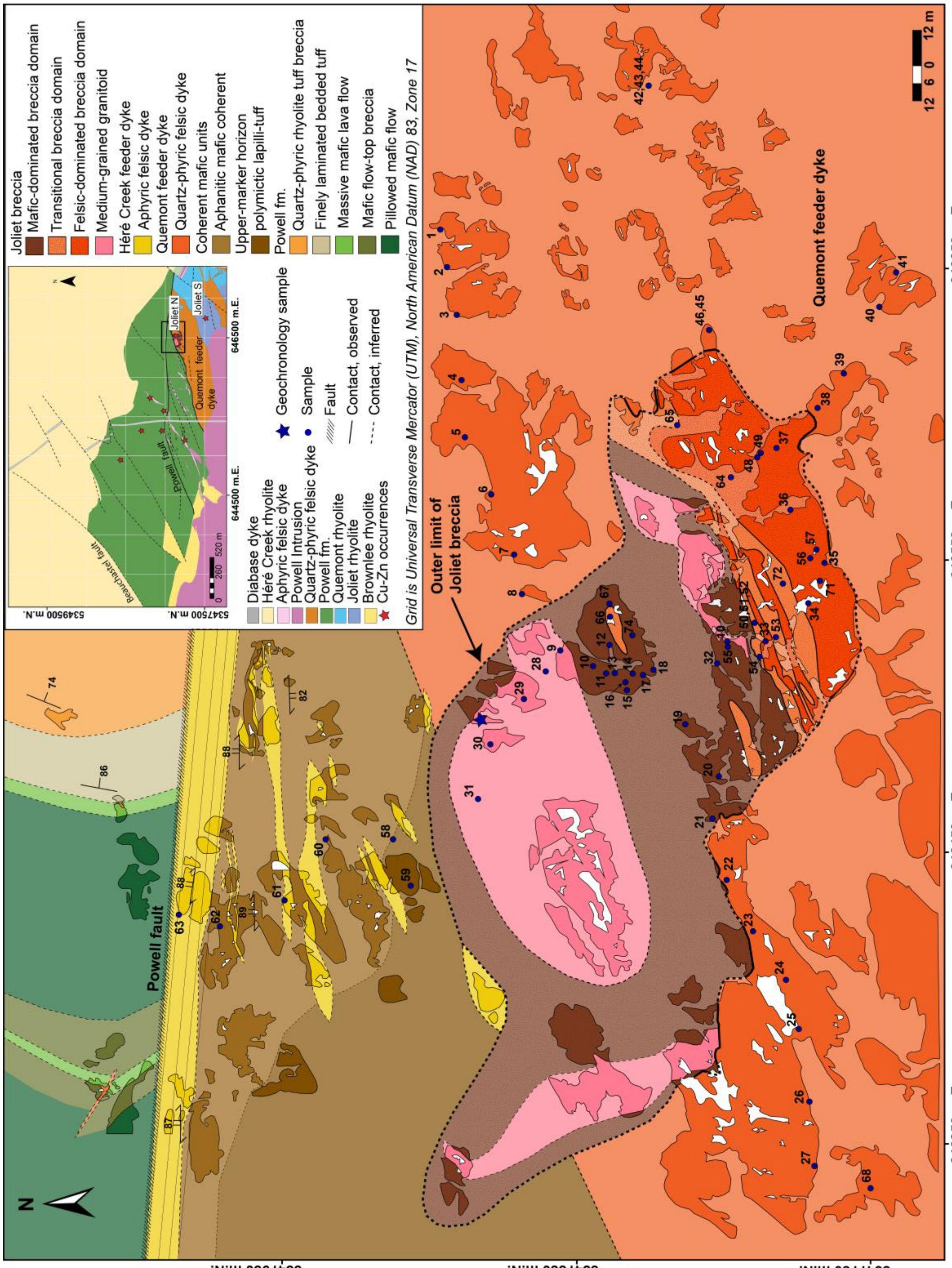

Figure 2. Geology at 1:500 scale of the Joliet breccia. The map area is located 400 m north of the Joliet orebody (Figure 1) and the locations of the samples collected for whole-rock analysis (blue circles) and of the sample submitted for high-precision U-Pb geochronology (blue star) are also shown.

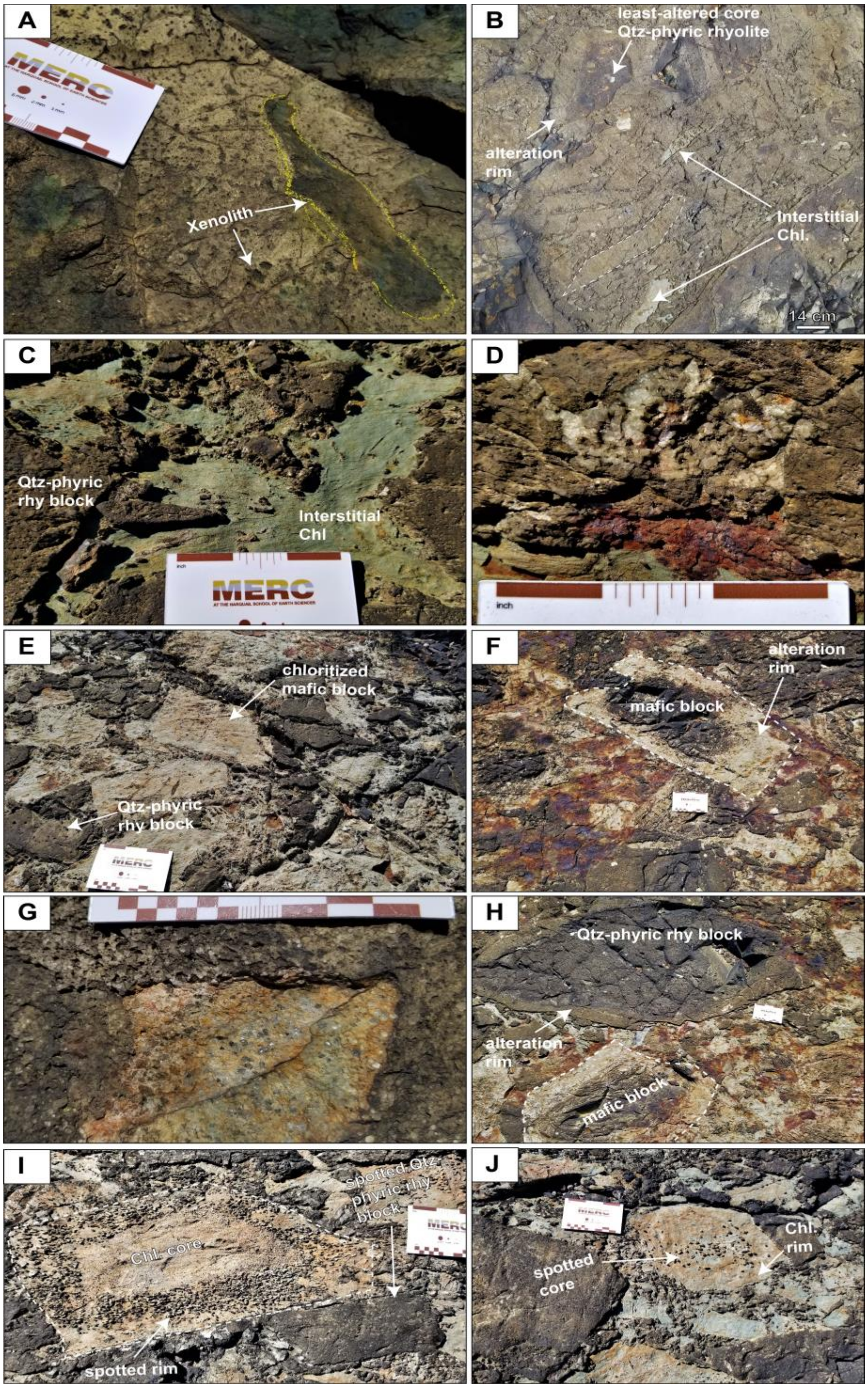

Figure 3. Field photographs showing: **a)** xenoliths in the Quemont feeder dyke; **b)** felsic-dominated domain of Joliet breccia, with shape of tabular clast highlighted with white dashed line; **c)** chlorite (Chl) infilling the negative space between quartz-phyric rhyolite (rhy) fragments in felsic-dominated domain; **d)** vuggy quartz (Qtz) and sulphide grains interstitial to fragments of quartz-phyric rhyolite; **e)** transitional domain, chloritized rectangular blocks and quartz-phyric rhyolite blocks; **f)** mafic-dominated domain, showing large mafic block with chlorite alteration rim and intense sulphide mineralization in the matrix; **g)** tonalite body within the breccia; **h)** sericite alteration rim around felsic block and chlorite alteration rim around mafic block in mafic-dominated domain; **i)** spotted alteration rim around mafic block in mafic-dominated domain; **j)** spotted core and chloritized rim of mafic block in mafic-dominated domain.