Quartz-Sulphide Mineralization and Associated Spotted Alteration within the Powell Block, Rouyn-Noranda, Quebec

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INTRODUCTION

This report is a summary of the data collected during the second field season of a four-year Ph.D. research project conducted by the first author, focused on the metallogeny of the Powell Block (PB) located in Rouyn-Noranda, Quebec. This research is part of the Metal Earth initiative, a seven-year project directed by the Mineral Exploration Research Centre at the Harquail School of Earth Sciences. The PB was chosen as it is a well-endowed part of the Abitibi greenstone belt, with uncertain stratigraphic correlations across adjacent fault blocks, and is considered a keystone for understanding the Au-enrichment processes in the adjacent volcanogenic massive sulphide (VMS) deposits. The PB hosts the Au-rich Quemont VMS deposit (14 Mt at 5.5 g/t Au, 331 g/t Ag, 1.32% Cu and 2.44% Zn) and separates the Horne deposit, a world-class Au-rich VMS deposit (54 Mt at 6.1 g/t Au, 13 g/t Ag, and 2.2% Cu), from conventional VMS deposits (≤1 g/t Au) north of the Beauchastel fault. In addition, orogenic-style quartz-carbonate-Au–vein mineralization is found along the Horne Creek fault (HCF) and crosscutting the Powell intrusion (e.g., Silidor, New Marlon, Powell–Rouyn mines).

New detailed geological mapping within the PB demonstrates the presence of widespread spotted alteration. Such alteration is well known in the Amulet–Millenbach area within the Noranda massive sulphide district, where it has historically been given the local name ‘dalmatianite’. This spotted rock, locally consisting of cordierite+anthophyllite±biotite, has been interpreted as a product of static metamorphism of previously altered volcanic rocks in the contact aureole of the ca. 2690 Ma Lac Dufault granodiorite (De-Rosen-Spence, 1969; Fitchett, 2012). However, this study shows that in the PB the spotted alteration occurs at some distance from granodiorite and is not associated with any known massive sulphide deposit but rather with quartz-sulphide vein mineralization. It likely delineates an upflow zone for hydrothermal fluids. Detailed mapping was executed to determine the spatial distribution of the spotted alteration, which has been found crosscutting all lithological units mapped to date. In addition, stratigraphic sections were completed along five fault blocks, three on the southern side of the Powell fault and two on its northern side, combined with detailed structural mapping to reconstruct the volcanic stratigraphy, and put the alteration and mineralization into a time-stratigraphic sequence.

REGIONAL GEOLOGY

The ca. 2704–2695 Ma Blake River group (BRG) of the southern Abitibi greenstone belt, comprises a bimodal submarine volcanic assemblage 12 000–15 000 m thick that is bound to the north by the Porcupine–Destor fault system and to the south by the Larder Lake–Cadillac fault system (Figure 1a; Baragar, 1968; Goodwin and Ridler, 1970; McNicoll et al., 2014). The BRG has several distinct volcanic centres, including the Noranda camp, which are characterized by the thickening of volcanic successions, an increased proportion of felsic volcanic rocks, and the presence of synvolcanic intrusions and associated synvolcanic faults (Spence and de Rosen-Spence, 1975; Gibson and Watkinson, 1990; McNicoll et al., 2014).

The Noranda camp sits in a conformable sequence, roughly 6000 m thick, of predominantly andesites and rhyolites 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). The volcanic units are generally only weakly metamorphosed to the lower greenschist facies, locally reaching up to the amphibolite facies within the contact aureole of the ca. 2690 Ma Lac Dufault pluton. They are relatively undeformed and lack widespread schistosity in rocks north of the PB. Primary volcanic textures are typically well preserved. Volcanic products are predominantly effusive volcanic flows, with minor pyroclastic activity marked locally by bedded tuffs and lenses of coarse breccia occurring proximal to interpreted eruptive centres (Spence and de Rosen-Spence, 1975).

An early synvolcanic extensional event is associated with cauldron collapse along east-northeast-trending synvolcanic faults (de Rosen Spence, 1976; Dimroth et al., 1983; Kerr and Gibson, 1993; Gibson and Galley, 2007). The rocks of the Noranda camp are folded into a broad, easterly plunging anticlinorium and a major synclinorium, bound to the north by the HCF and to the south by the Andesite fault. The subvolcanic Flavrian and Powell intrusions are located along the axis of the anticlinorium (Wilson, 1941; Spence and De Rosen-Spence, 1975).

LOCAL GEOLOGY

The PB (Figure 1b) is a wedge-shaped fault block and one of several structural blocks that comprise the Rouyn–Noranda district (De Rosen-Spence, 1976). The PB is bounded by the Beauchastel fault to the north and the HCF to the south, and contains several internal faults and shear zones (Wilson, 1941). Some of the internal east-northeast-trending faults are locally occupied by dikes and are inferred to be synvolcanic (e.g., Powell F-zone, Figure 1c). The most prominent, continuous internal fault is the east–west-trending Powell fault (Figure 1b), which is subparallel to the bounding Beauchastel and Horne Creek faults and marks a major offset in stratigraphy as well as a change in the orientation of strata. In addition to being offset along several fault blocks, the stratigraphy is folded into the east-southeast-plunging Powell syncline. To reconstruct the volcanic stratigraphy, stratigraphic sections were completed within several fault blocks, with a type section executed along the hinge of the Powell syncline (Figure 1b). The volcanic stratigraphy will be described in reference to the type section.

The western side of the PB contains the ca. 2700.1 ±1.0 Ma Powell pluton (McNicoll et al., 2014), inferred to be synvolcanic and subvolcanic with respect to overlying volcanic rocks and the heat source for VMS mineralization (Goldie, 1976; Kennedy, 1985; Cathles, 1993; Hannington et al., 2003). The Powell pluton, consisting of an earlier quartz-diorite phase and a later tonalite phase, intrudes, and hence is younger than, the lowermost stratigraphic unit within the PB, the Brownlee rhyolite, a lobed, aphyric-spherulitic-amygdaloidal–textured rhyolite flow. Overlying the Brownlee rhyolite is a succession (approximately 358 m thick) of andesite to basaltic-andesite massive flows, pillowed flows and breccia. Increasing amygdule content toward the top of flows, amygdule shape (flat bottom and rounded top) and pillow morphology indicate east-northeast-side-up within the hinge of the Powell syncline and to the south on the northern limb of the Powell syncline. Within the mafic succession, there is a marker unit (termed V9b by Morris, 1957) 8 m thick composed of aphryic rhyolite volcaniclastic material, grading from lapillistone to lapilli tuff to tuff (Figure 2). This marker unit is distinctive, with very sharp lower and upper contacts, the lower contact following the local topography of the underlying pillows. Large blocks of broken pillows were observed within the lower rhyolite lapillistone. The unit has been observed on either side of the Powell fault and serves as a useful measure of the amount of offset along this structure.

An aphyric rhyolite flow sequence approximately 50 m thick occurs up section, just before the Powell F-zone (Figure 1b), but this unit differs from the lower Brownlee rhyolite in that it is not amygdaloidal. An east–west section across the Powell F-zone consists of a succession of quartz-phyric rhyolite approximately 115 m thick, which grades from a coherent rhyolite flow to a proximal, crudely bedded jigsaw-fit breccia, with minor variations in fragment size and abundance. Overlying the quartz-phyric rhyolite breccia is a succession approximately 195 m thick of alternating finely bedded mafic tuff, massive andesite flows, pillowed flows and breccia. Interbedded within the mafic tuff are beds of quartz-phyric rhyolite tuff breccia. This is capped by approximately 30 m of lobed aphyric rhyolite flows, followed by approximately 100 m of mafic breccia, bedded tuff and massive andesite. Finally, the uppermost observed unit in this continuous stratigraphic package within the hinge of the Powell syncline is aphyric rhyolite, which is truncated by the Powell fault and crosscut by a late diabase dike. This sequence appears to be repeated, at least in part, within the four other stratigraphic sections measured this summer within adjacent fault blocks.

STRUCTURAL GEOLOGY

The main foliation (S_2) observed in the area strikes east–west and is axial planar to east-trending F_2 folds (e.g., Powell syncline). It formed during D_2, post-Timiskaming (ca. 2672 Ma) north–south shortening (Carrier et al., 2000; Poulsen, 2017). Parasitic S-shaped folds with an east-southeast plunge were observed on the northern limb of the Powell syncline, near the Powell fault. In addition, intensification of the axial planar cleavage, which remains clockwise to bedding, occurs toward the northern part of the map area proximal to the Powell fault. Within 4 m of the Powell fault, a vertical structural lineation defined by elongated spots is present, in addition to a near vertical mineral lineation, locally defined by alternating quartz and sericite streaks (trending approximately south-southwest). On vertical surfaces, shear bands and asymmetrical strain shadows around carbonate-vein clasts suggest north-side-up movement along the Powell fault, parallel to the lineation. The Powell fault underwent minor dextral reactivation, as suggested by the presence of a weak cleavage oriented east-northeast anticlockwise to bedding and axial planar to east-northeast-trending Z-folded quartz veins. The lack of major dextral movement along the Powell fault, as indicated by the few dextral kinematic indicators, contradicts the apparent dextral offset of approximately 700 m of the V9b tuff marker unit. Another weak-spaced cleavage, oriented east-northeast to east-southeast is found locally at boundaries between high- and low-strain zones, resulting in sinistral dragging of the main foliation along the fracture plane. Sinistral dragging of the main foliation is also observed at lithological contacts. This spaced cleavage is found overprinting parasitic S-folds near the Powell fault, with sinistral dragging of the axial planar foliation. In addition, northwest-striking sinistral kink bands and northeast-striking dextral kink bands are observed locally within sericitized rhyolite.

MINERALIZATION

The Noranda camp hosts 22 Cu-Zn-Au-Ag VMS deposits and 17 orogenic-Au deposits (Gibson and Watkinson, 1990). Late Au–quartz-carbonate deposits occur mainly in the Archean tonalite plutons of the Blake River group (e.g., Silidor, New Marlon, Powell–Rouyn mines associated with the Powell pluton; Elder, Pierre-Beauchemin mines, with the Flavrian pluton; Carrier et al., 2000). The VMS deposits within the Noranda camp, occur in the Noranda formation (Goutier et al., 2006; Gibson and Galley, 2007) and range in age from the ca. 2702 Ma Au-rich Horne and Quemont deposits, which are among the oldest deposits of the BRG (Mercier-Langevin et al., 2011), to the ca. 2698 Ma Cu-Zn–rich deposits of the central Noranda camp (David et al., 2006; McNicoll et al., 2014). Whereas the Quemont (14 Mt at 5.5 g/t Au, 331 g/t Ag, 1.32% Cu and 2.44% Zn) and Horne deposits (54 Mt at 6.1 g/t Au, 13 g/t Ag and 2.2% Cu) are anomalous in size and Au grade, deposits north of the Beauchastel fault are typically Cu-Zn rich and are less Au endowed (≤1 g/t Au; Gibson and Galley, 2007).

The central Noranda camp Cu-Zn–bearing VMS deposits contain abundant pyrrhotite and are hosted within the 2698.5 ±2 Ma (David et al., 2006) Cycle III rhyolite, also known as the 'Mine Zone'. Zinc-rich VMS deposits contain abundant pyrite and are hosted within the Cycle IV rhyolite (Spence and de Rosen-Spence, 1975; Gibson and Galley, 2007). The Amulet andesite, which is interpreted south of the

Beauchastel fault as being equivalent to the Powell andesite (Wilson, 1941), separates the Cycle III and Cycle IV rhyolites (Spence and de Rosen-Spence, 1975). Other than the Quemont deposit, no substantial VMS deposits have been found within the PB; however, numerous occurrences of quartz-pyrite-chalcopyrite veins (e.g., Powell B-, D- and F-zones, and Anglo A- and C-zones; Figure 3a, b) have been documented to crosscut every rock unit mapped to date. This mineralization is commonly found proximal to felsic dikes, which mark offsets in volcanic stratigraphy, and coincides with zones of intense spotted alteration.

The quartz-pyrite-chalcopyrite veins are overprinted by the foliation and lineation, and are surrounded by alteration spots that are flattened parallel to the regional foliation (Figure 3c, d). The veins therefore predate regional deformation of the PB and, as they are located along the margin of felsic feeder dikes, are likely associated with early synvolcanic faulting.

ALTERATION

Two types of spotted alteration have been observed: ovoid and idiomorphic (Figure 3e, f). The ovoid spots consist of clusters 1 mm–1 cm in diameter of fine-grained sericite and quartz, within a chloritized matrix, which are widely distributed in the study area. First noted by Wilson (1941) as 'peculiar protuberances', they were subsequently described by Lichtblau and Dimroth (1980) as altered alkali feldspar-quartz spherulites. However, the structurally controlled distribution of the spots proximal to quartz-sulphide veins (Figure 3a) and lack of distinctive spherulites outside of the alteration halo imply that a hydrothermal origin is more likely. Interestingly, a similar 'spotted alteration' zone was also observed at the Corbet mine, outside of the Lac Dufault contact aureole and spatially related to the quartz-diorite phase of the Flavrian pluton (Knuckey and Watkins, 1982). The idiomorphic spots are 1–2 cm in diameter and occur locally as topographic highs, which occasionally coalesce, within recessively weathered massive chlorite-alteration patches (Figure 3e). It is possible that the idiomorphic spots represent retrograded metamorphic porphyroblasts formed in areas that witnessed premetamorphic hydrothermal alteration in a process similar to that which produced the dalmatianite found in the central Noranda camp and the ovoid spots represent a different, but related, manifestation of metamorphosed alteration. In addition, it is noteworthy that the most intense alteration adjacent to the veins within the PB is typically non-spotted and composed of fine-grained massive chlorite (Figure 3a). Sericite alteration is also prominent within the rhyolite flows and felsic dikes, and occurs locally as rims surrounding clasts within rhyolite breccias.

CONCLUSIONS

Spotted alteration is structurally controlled, occurs proximal to quartz-sulphide mineralization and has been observed in every unit mapped to date, including the Powell intrusion. The spots are interpreted to represent a retrogressed manifestation of metamorphosed alteration. The original porphyroblasts, and spot compositions and potential heat source(s) for metamorphism, require further investigation. The quartz-sulphide mineralization event is interpreted as synvolcanic and overprinted by later deformation. Notably, the mineralization and associated spotted alteration indicate hydrothermal up-flow zones, proximal to synvolcanic structures, which can be used as an exploration tool to target VMS mineralization.

Regional deformation resulted in a main east–west cleavage, axial planar to the Powell syncline and overprinting the quartz-sulphide veins. In addition, associated alteration spots are flattened parallel to the main cleavage outside of the Powell fault zone, and flattened and elongated within the Powell fault zone. Later dextral and sinistral shear-sense indicators are also observed proximal to the Powell fault, suggesting that minor dextral and sinistral reactivation followed the main north-over-south movement along the fault. Stratigraphic units are offset into numerous fault blocks and measurements of preliminary stratigraphic sections on either side of the Powell fault suggest that correlations can be made using the V9b tuff marker unit to estimate the amount of offset along the Powell fault, which has an apparent dextral offset on the order of 700 m.

FUTURE WORK

Further work over the fall and winter months will attempt to establish stratigraphic correlations among all the fault blocks, using the stratigraphic sections to put the mineralization into a stratigraphic context. Detailed petrography is required on samples of quartz-sulphide mineralization, in addition to the ovoid and idiomorphic spots. Lithogeochemical analyses are pending for spotted and non-spotted samples to evaluate the intensity of metasomatism and to determine the potential precursor porphyroblast(s) for the spots. In addition, detailed mapping is required next field season of the Au-quartz-carbonate veins at the Silidor, Anglo–Rouyn, New Marlon and Powell–Rouyn mines to determine their relative timing with respect to deformation, with a specific focus on the scale of related carbonate alteration. The Joliet breccia in the eastern portion of the PB is located along the margin of a large quartz-phyric rhyolite dike and will also require detailed mapping over the next field season as it appears to be a locus for spotted alteration and disseminated copper mineralization.

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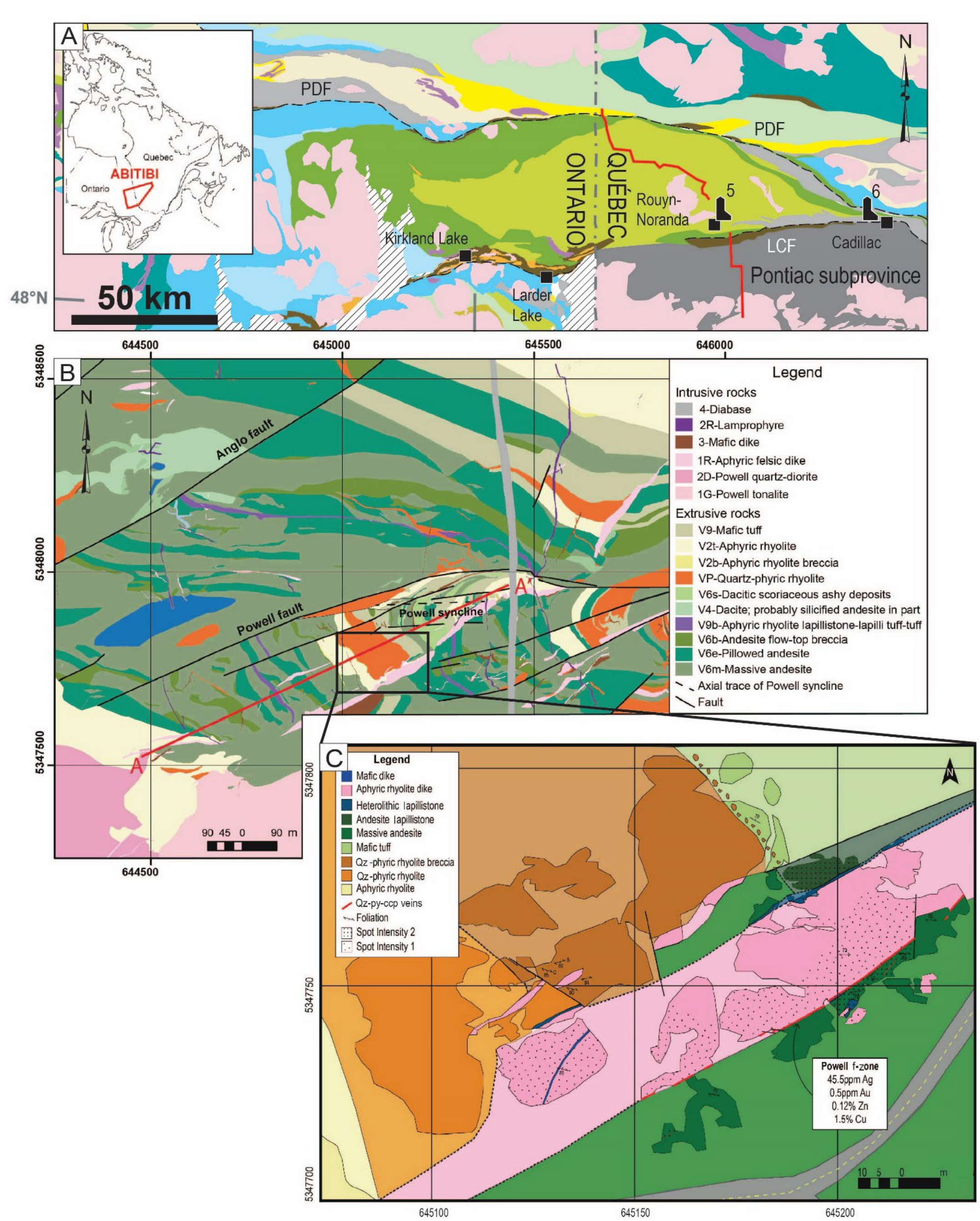

Figure 1. a) Location map of the Noranda camp within the Abitibi greenstone belt (Thurston et al., 2008), with Metal Earth Rouyn-Noranda transect shown in red, as well as the Horne mine (5) and LaRonde-Penna mine (6); **b)** geological map of the Powell block (figure *modified from* Morris, 1957); red line (A–A') shows stratigraphic type section that was executed within the hinge of the Powell syncline and box with black outline shows location of Figure 1C; **c)** detailed map of Powell F-zone, showing distribution of spotted alteration and quartz-pyrite-chalcopyrite mineralization; inset shows the assay values from a vein sample collected in 2017. Abbreviations: ccp, chalcopyrite; LCF, Larder Lake–Cadillac fault; PDF, Porcupine–Destor fault; py, pyrite; qz, quartz.

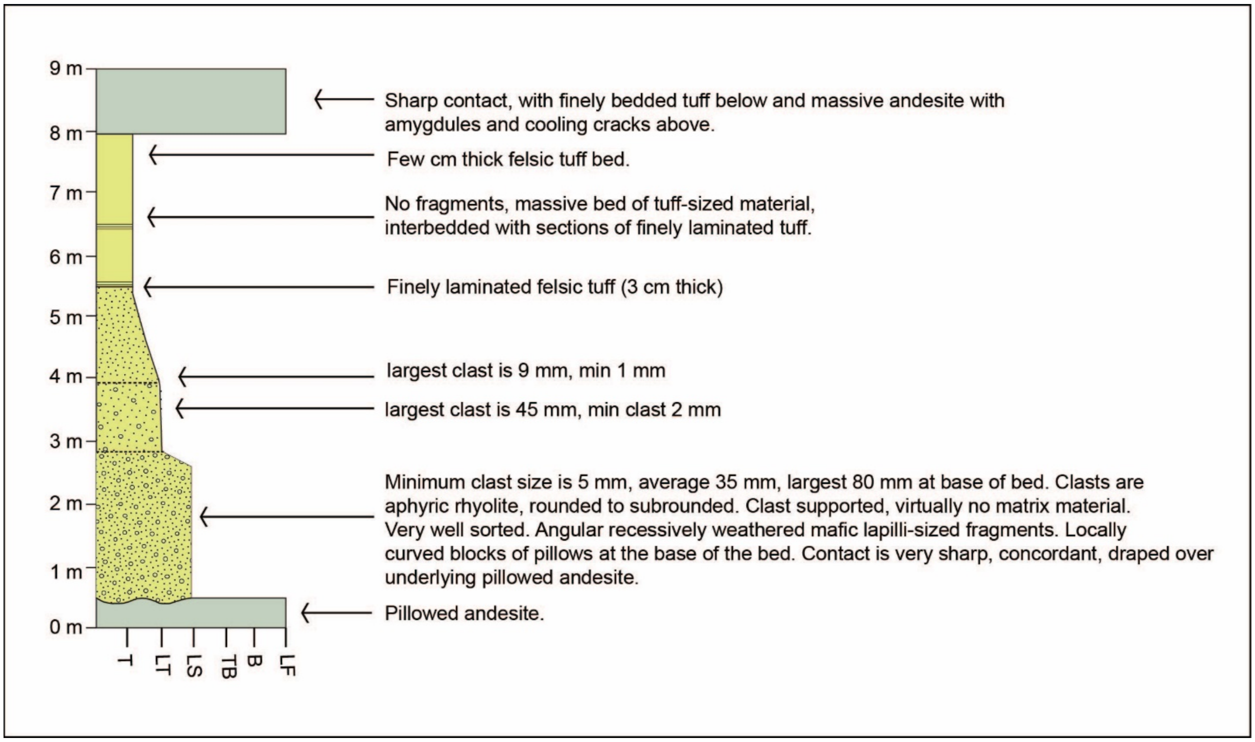

Figure 2. Stratigraphic section of V9b tuff marker unit (Morris, 1957) from the type section (A–A' in Figure 1B). Abbreviations: T, tuff; LT, lapilli tuff; LS, lapillistone; TB, tuff breccia; B, breccia; LF, lava flow.

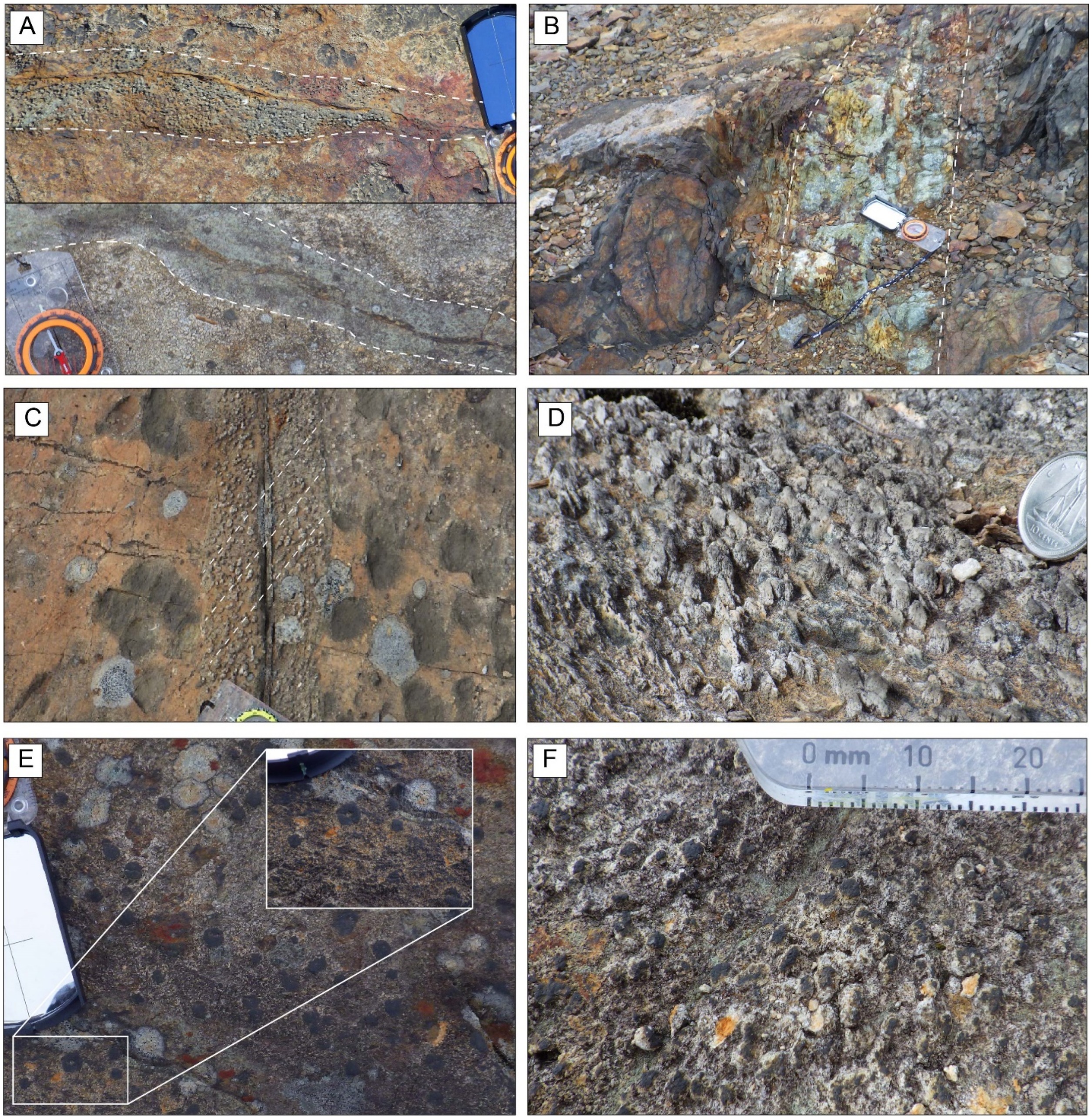

Figure 3. Field photographs showing: **a)** Anglo A-zone quartz-sulphide veins with spotted-alteration halo (top) and chlorite-alteration halo (bottom); **b)** Powell F-zone quartz-pyrite-chalcopyrite vein; **c)** halo of alteration spots surrounding a quartz-sulphide vein near the Powell F-zone, with spots flattened to contribute to a metamorphic foliation; **d)** flattened and elongated alteration spots along the Powell fault, defining a vertical lineation; **e)** idiomorphic spots overgrowing ovoid spots (inset) at the Anglo A-zone; **f)** ovoid spots at the Anglo A-zone.