# Volcanic stratigraphy and intrusions in the Renault–Dufresnoy and Duprat–Montbray formations: implications for metal endowment in the lower Blake River group, Rouyn-Noranda, Quebec

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## INTRODUCTION

Metal Earth is a geoscience project funded by the Canada First Research Excellence Fund and operated by the Mineral Exploration Research Centre at the Harquail School of Earth Sciences. The preliminary work presented here is part of a two-year M.Sc. research project funded by Metal Earth that will focus on the metallogeny of volcanic strata in a square-shaped area of ~90 km² along Chemin de la Mine, 30 km northwest of Rouyn-Noranda, Quebec (Figure 1).

Volcanic and volcaniclastic rocks in the study area belong to two formations that are part of the lower Blake River group (BRG), the 2702–2696 ±0.8 Ma Renault–Dufresnoy formation (RDF) and the 2702 Ma Duprat–Montbray formation (DMF; Figure 2; McNicoll et al., 2014). Volcanic rocks in both formations are intermediate to mafic, whereas volcaniclastic rocks are intermediate to mafic in the RDF (Ross et al., 2011) but felsic in the DMF (Liaghat and MacLean, 1995). The field area also includes two ellipsoidal synvolcanic felsic intrusions covering ~6 km², the Monsabrais pluton (Ross et al., 2008) in the RDF and the Fabie pluton (McNicoll et al., 2014) in the DMF. Both formations also host small (<2 km²), younger intrusions of intermediate compositions. The contact between the RDF and DMF is the east-striking Baie Fabie shear zone (BFSZ). The metamorphic grade in the area varies from subgreenschist to greenschist facies (Ross et al., 2008). Two rhyolite-hosted volcanogenic massive sulphide (VMS) deposits, Fabie and Magusi, occur within the DMF (Meyers and McLean, 1983; Liaghat and MacLean, 1995). These deposits were mined and produced 1.3 Mt, with an average grade of 1.99 % Cu, 4.12 % Zn, 42.8 g/t Ag and 1.27 g/t Au.

The main goals of the project are to: 1) define the contact relationships between the RDF and DMF; 2) establish a stratigraphy for the DMF; and 3) construct the volcanic setting/environment for the two VMS deposits.

## GEOLOGICAL SETTING

In the study area, the contact between the RDF and DMF is the BFSZ (Figure 2). The RDF conformably overlies the rhyolite of the 2702 ±1.0 Ma Hébécourt formation to the north (Rogers et al., 2014), which provides a maximum age for the RDF (McNicoll et al., 2014). North of the BFSZ, strata of the RDF trend east-northeast and young consistently toward the south. South of the BFSZ, strata of the DMF maintain an approximately east-west orientation and young toward the north (Liaghat and MacLean, 1995).

The RDF consists of basaltic–andesitic volcanic and volcaniclastic rocks of similar composition (Figure 2). Ross et al. (2011) documented an erosional contact between truncated pillowed flows and overlying volcaniclastic units that locally shows crossbedding (Figure 3a, b); the volcaniclastic deposits were interpreted as the product of the interaction of explosive magma and water (Ross et al., 2011). The minimum age for the RDF is provided by the Monsabrais pluton (Figure 2; Ross et al., 2008), which has been interpreted as a synvolcanic intrusion (McNicoll et al., 2014).

The DMF is dominated by basaltic to andesitic flows and rhyolites that are either coherent or volcaniclastic (Figure 2; Liaghat and MacLean, 1995). The uppermost volcaniclastic rhyolite in the DMF (Figure 4a, b) is host to the Fabie and Magusi VMS deposits, formerly known as the New Insco and Iso deposits, respectively (Meyers and MacLean, 1983; Liaghat and MacLean, 1995). The VMS-hosting rhyolite yields an age of 2701 ±1.0 Ma (McNicoll et al., 2014), which constrains the age of the Fabie and Magusi deposits, and is considered a minimum age for the DMF. The 2700 ±1.0 Ma synvolcanic Fabie pluton (McNicoll et al., 2014) intrudes the DMF and is located southwest of the two VMS deposits (Figure 2).

# RESULTS OF SUMMER FIELDWORK

## Supracrustal Rocks

The RDF strata consist of andesitic volcanic flows rich in plagioclase phenocrysts (up to 35%), quartz (30%) and amphibole (35%). The volcanic rocks are often pillowed and contain moderate to high amounts of vesicles (15–50%; Figure 3c) that are commonly filled with quartz and epidote, and occasionally calcite. In the pillowed flows, hyaloclastite is observed between pillow selvages (Figure 3d) and amygdules, along with concentric cooling cracks, are concentrated along pillow margins. The volcaniclastic units are bedded, where bedding is defined by changes in grain size, and are often intercalated with flows. Clast sizes and percentages are variable and have been subdivided into tuff breccia (Figure 3e), lapilli tuff and lapillistone using the classification scheme of Fisher (1961). The clasts display the same textures as the volcanic flows and are basaltic to andesitic in composition (Ross et al., 2011). Pillows and crossbedding indicate a younging direction toward the southeast (Figure 3b).

The DMF stratigraphy differs from the RDF in both composition and texture. The DMF pillowed volcanic rocks contain fewer amygdules and the younging direction, generally toward the northwest, is opposite to that of the RDF (Figure 4c). The DMF contains aphyric rhyolite as either very fine grained, massive, coherent units or as volcaniclastic rocks (Figure 4a, b). Alteration is dominantly silica and epidote (secondary crystals in amygdules and veins, and disseminated throughout the groundmass), as well as pervasive chlorite, sericite and carbonate in more intensely altered rocks that are spatially associated with the VMS deposits (Liaghat and MacLean, 1995).

## Intrusions

The Monsabrais pluton is a coarse-grained, massive tonalite and the oldest intrusion in the RDF. Volcanic rocks near the intrusion do not display recrystallization textures indicative of contact metamorphism or of increasing metamorphic grade as the intrusion is approached (Figure 3f). The Fabie intrusion is a synvolcanic, quartz-feldspar porphyry intrusion located ~2 km southwest of the Fabie deposit (Figure 2). Throughout the intrusion, the mineralogy remains consistent as coarse-grained plagioclase and quartz phenocrysts are hosted in a fine- to medium-grained groundmass of similar composition. Volcanic rocks at the contact are not contact metamorphosed, and the contact is sharp and irregular (Figure 4d).

Smaller diorite intrusions that intrude the volcanic rocks often display chilled margins. The diorite is typically massive and fine to medium grained, with a granular texture. The mineralogy consists of plagioclase (60%) and amphibole (40%), along with quartz and chlorite. Where the diorite intrudes the Fabie intrusion, the latter is brecciated at the contact with the diorite. The breccia consists of 0.5–3 cm clasts of the Fabie quartz-feldspar porphyry in an intermediate matrix (Figure 4e). Other intrusive rocks in the map area include later magnetite-bearing diabase dykes and coarse-grained gabbroic dykes.

### The Fabie and Magusi VMS Deposits

The two VMS deposits (Figure 2) occur stratigraphically above the volcaniclastic rhyolite. At the Fabie and Magusi deposits, the ore is overlain by pillowed and massive mafic to andesitic flows. Alteration spatially associated with the VMS deposits consists of intense, pervasive and vein-style chlorite and sericite, whereas the volcanic rocks distal (>500 m) to the former mines are characterized by dominantly moderate to pervasive and vein-style epidote-quartz alteration, with minor chlorite.

### Structural Geology

The contact between the RDF and DMF is the BFSZ, across which the formations have opposing facing directions (Figure 2). The BFSZ was not observed in the field; however, a narrow parallel deformation zone was observed along the southern shoreline of Baie Magusi, with calcite occurring in open cavities within more highly foliated, coherent mafic rocks. This deformation zone, which may be a splay from the BFSZ, strikes northeast and dips steeply to the southeast, and contains a steep southwest-plunging lineation. A relatively weakly developed S-C fabric observed in plan view suggests sinistral movement (Figure 4f).

## DISCUSSION

The RDF and DMF are different in terms of composition and age. The following points indicate the issues and research work that are supported by observations made in the field:

- The felsic intrusive rocks in the map area differ in composition and texture (Ross et al., 2008; McNicoll et al., 2014). Preliminary work to date supports synvolcanic emplacement, based on the lack of contact metamorphic features. The diorite, which intrudes volcanic units and the Fabie pluton, is found in younger intrusions. The Fabie pluton yields an age that is similar to the overlying rhyolite, whereas the Monsabrais pluton yields an age significantly younger than the lowermost RDF strata. This implies that the upper RDF could be younger than 2696 Ma.

- The contact between the RDF and DMF is the BFSZ, but the kinematic history of the shear zone is not understood. Investigation of the deformation zone subparallel to the BFSZ this field season would seem to suggest that at least two different episodes of fault movement, strike-slip indicated by a weak S-C fabric in plan view and a down-dip lineation, occurred. This suggests that the BFSZ was reactivated at least once and potentially constitutes a long-lived structure. However, further investigation is required to understand the history of the BFSZ.

- The volcanic stratigraphy that hosts the Fabie and Magusi deposits is not fully understood. One outstanding question is whether or not the Fabie pluton served as an important heat source for both deposits (Galley, 2003; Franklin et al., 2005). Comparison of the chemostratigraphy of DMF rhyolite in the map area with that of the Fabie intrusion in the DMF has never been done. Understanding this relationship is critical in determining the ore-forming processes that led to VMS mineralization.

## FUTURE WORK

Through geological mapping, geochemistry and geochronology, this M.Sc. project will establish the relationship between volcanic and intrusive units within the upper part of the DMF to better understand not only the setting of both VMS deposits, but also their volcanic and deformation history, as well as the role of the synvolcanic Fabie intrusion. The hydrothermal footprint of these deposits will also be determined in order to further constrain the mineralization potential of the area.

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## REFERENCES

Fisher, R.V. 1961. Proposed classification of volcaniclastic sediment and rocks; Geological Society of America Bulletin, v. 72, p. 1409–1414.

Franklin, J.M., Gibson, H.L., Jonasson, I.R. and Galley, A.G. 2005. Volcanogenic massive sulfide deposits; Economic Geology 100th Anniversary Volume, p. 523−560.

Galley, A.G. 2003. Composite synvolcanic intrusions associated with Precambrian VMS- related hydrothermal systems; Mineralium Deposita, v. 38, p. 443−473.

Liaghat, S. and MacLean, W.H. 1995. Lithogeochemistry of altered rocks at the New Insco VMS deposit, Noranda, Quebec; Journal of Geochemical Exploration, v. 52, no. 3, p. 333–350.

McNicoll, V., Goutier, J., Dubé, B., Mercier-Langevin, P., Ross, P-S., Dion, C., Monecke, T., Legault, M., Percival, J. and Gibson, H. 2014. U-Pb geochronology of the Blake River Group, Abitibi greenstone belt, Quebec, and implication for base metal exploration; Economic Geology, v. 109, p. 27–59.

Meyers, R.E. and MacLean, W.H. 1983. The geology of the New Insco copper deposit, Noranda district, Quebec; Canadian Journal of Earth Sciences, v. 20, p. 1291–1304.

Rogers, R., Ross, P.-S., Goutier, J. and Mercier-Langevin, P. 2014. Using physical volcanology, chemical stratigraphy, and pyrite geochemistry for volcanogenic massive sulfide exploration: an example from the Blake River Group, Abitibi greenstone belt; Economic Geology, v. 09, p. 61–88.

Ross, P.-S., Goutier, J., McNicoll, V.J. and Dubé, B. 2008. Volcanology and geochemistry of the Monsabrais area, Blake River Group, Abitibi Greenstone Belt, Quebec: implications for volcanogenic massive sulphide exploration; *in* Current Research. Geological Survey of Canada, Paper 2008-1. p. 1–18.

Ross, P-S., Goutier, J., Mercier-Langevin, P. and Dubé, B. 2011. Basaltic to andesitic volcaniclastic rocks in the Blake River Group, Abitibi greenstone belts: 1. Mode of emplacement in three areas; Canadian Journal of Earth Sciences, v. 48, p. 728–756.

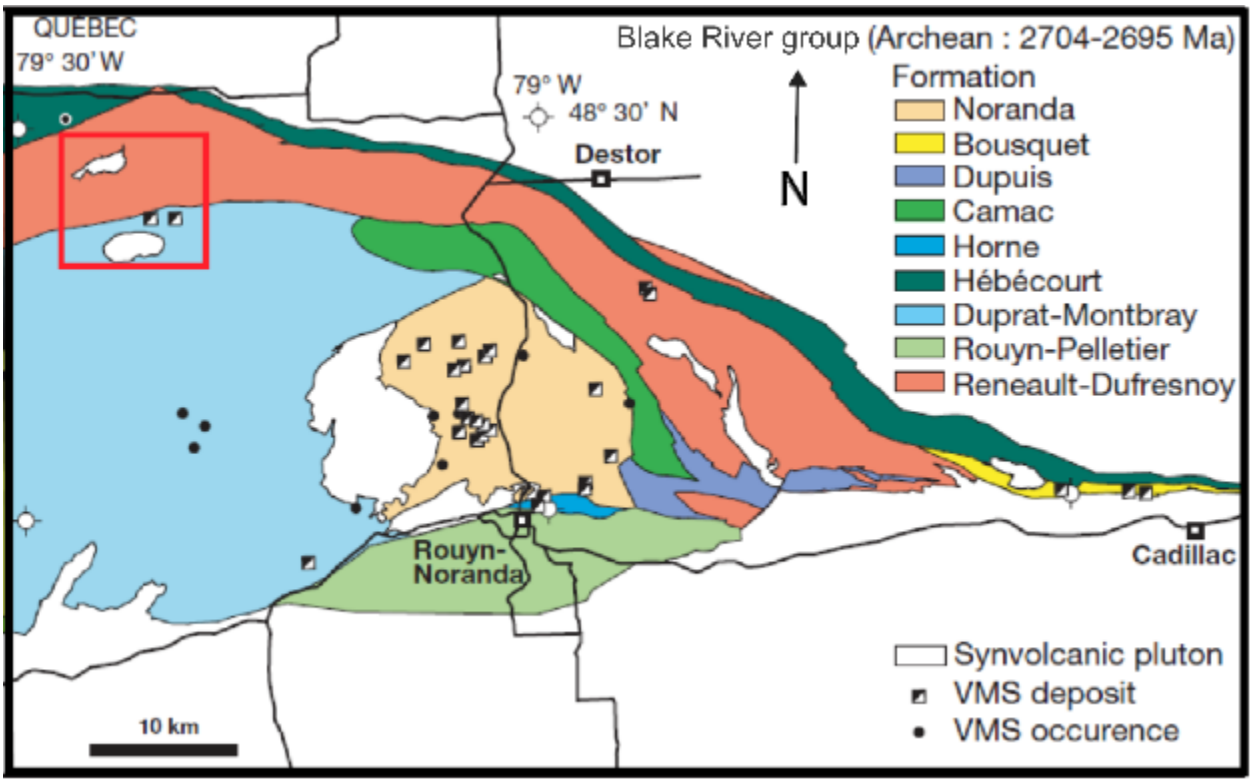


**Figure 1.** Stratigraphic subdivision of the Blake River group in Ontario and Quebec. Red square indicates study area of the summer 2017 mapping project, located around the contact of the Renault–Dufresnoy and Duprat–Montbrey formations (image modified from McNicoll et al., 2014). Abbreviations: Ma, millions years before present; VMS, volcanogenic massive sulphide.

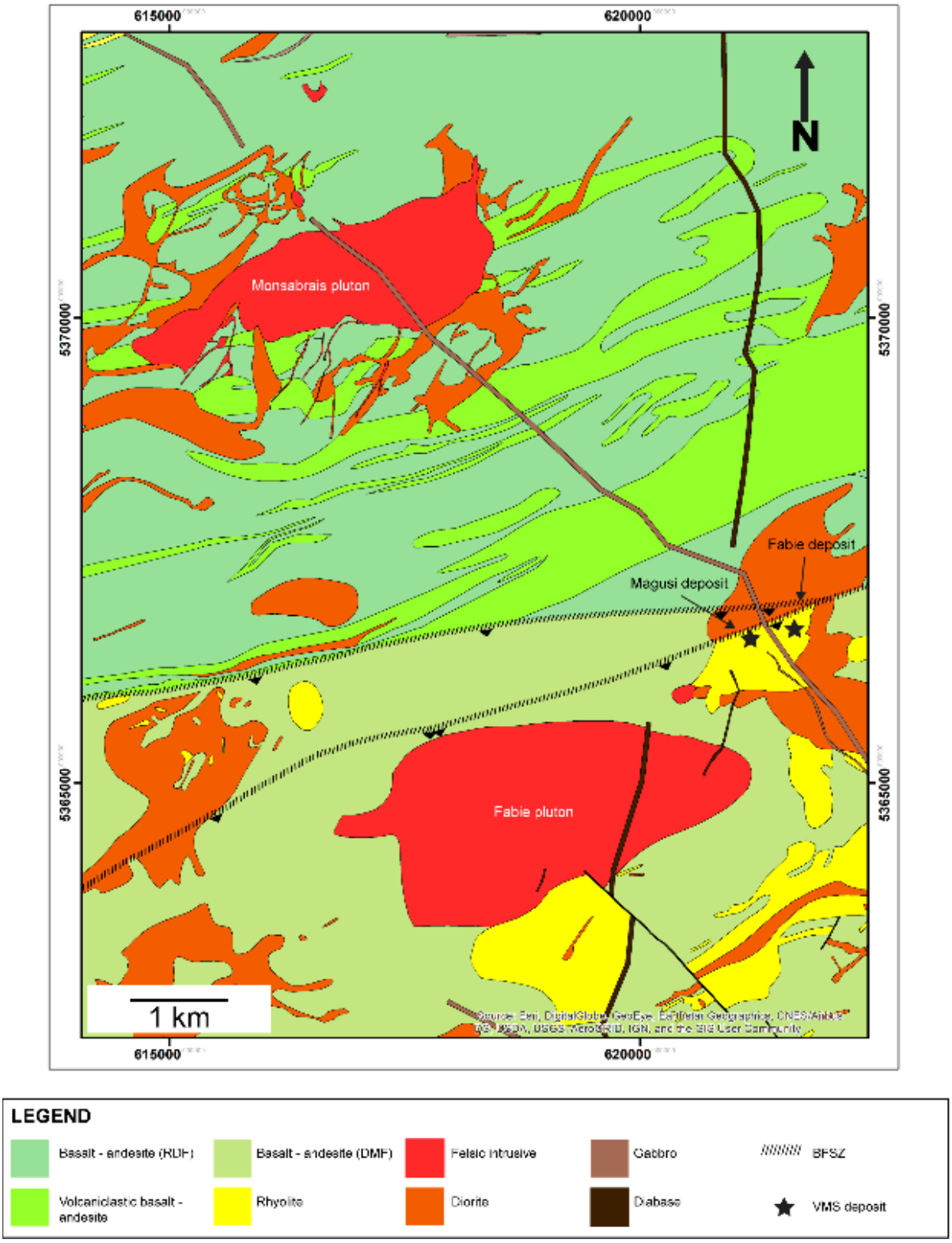


**Figure 2.** Geology of the 2017 field-mapping project study area, showing the various rock units within the Renault–Dufresnoy formation (northern unit) and Duprat–Montbray formation (southern unit) in the Rouyn-Noranda area. Triangles located near the BFSZ indicate which block was thrust above the other. Abbreviations: BFSZ, Baie Fabie shear zone; VMS, volcanogenic massive sulphide.

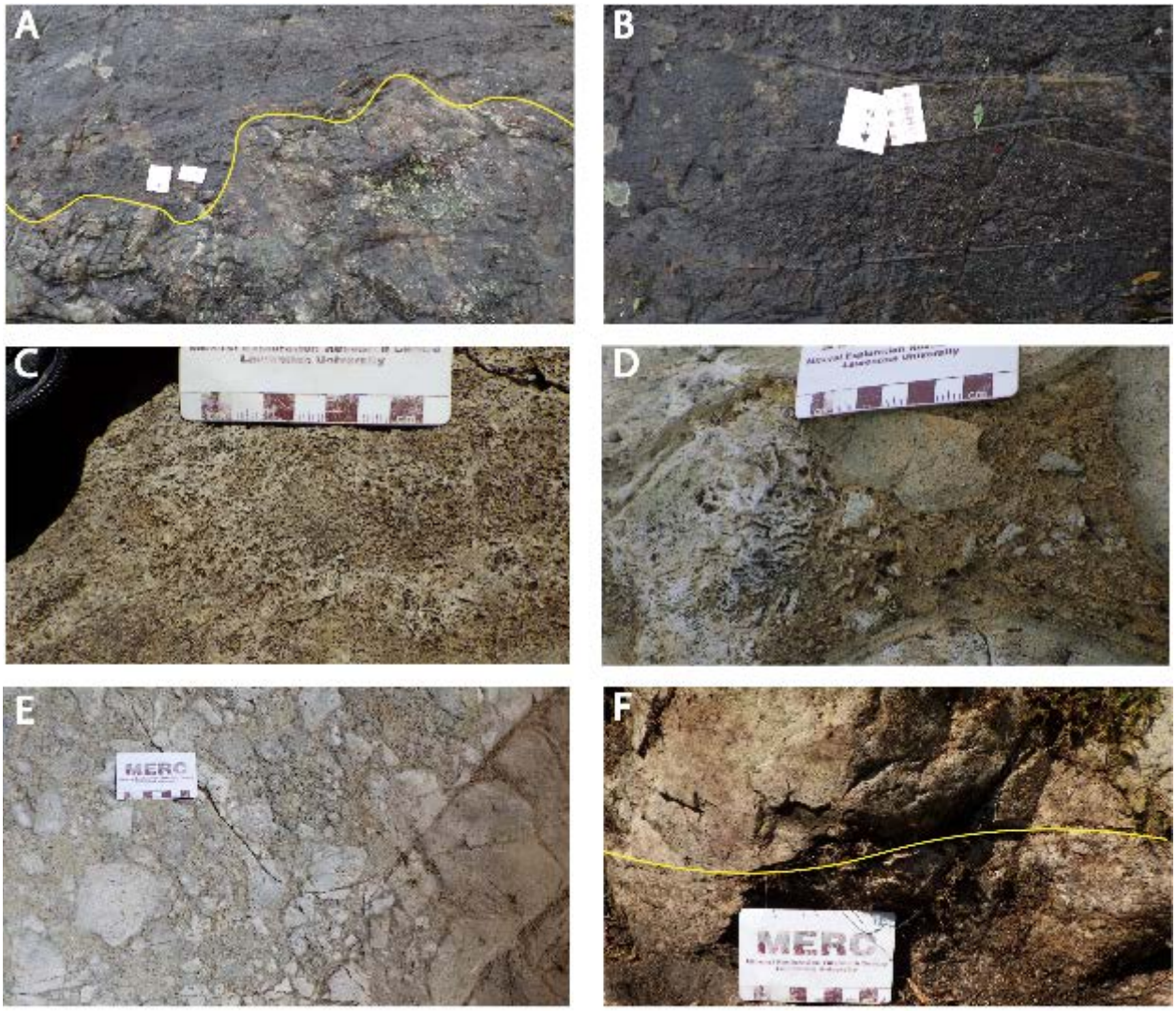


**Figure 3.** Outcrop photographs of the Renault–Dufresnoy formation in the Rouyn-Noranda area, showing **a)** an erosional contact at an outcrop, previously mapped and interpreted by Ross et al.(2011), that serves as an unconformity between pillowed volcanic rocks (bottom) and intermediate volcaniclastic bedded units (top); **b)** crossbedding at an outcrop, previously interpreted and mapped by Ross et al. (2011), indicating younging toward the southeast; **c)** a vesicular volcanic unit, with modal abundance of vesicle diameter reaching up to 5 mm in length and total abundance of vesicles estimated at 50%; **d)** hyaloclastite observed within pillow selvages; **e)** tuff breccia composed of basalt–andesite clasts that show similar textures to the volcanic units, such as vesicles, amygdules and chilled margins; **f)** a contact between the Monsabrais pluton (bottom) and the basaltic–andesitic volcanic rocks. Yellow lines indicate contact between units.


**Figure 4.** Outcrop photographs of the Duprat–Montbray formation in the Rouyn-Noranda area, showing **a)** volcaniclastic rhyolite that is proximal to the Fabie deposit and is interpreted as hosting the volcanogenic massive sulphide deposit at depth (Meyers and MacLean, 1983); **b)** volcaniclastic rhyolite observed northwest of the Fabie pluton; **c)** pillow selvages observed on a basalt–andesite volcanic unit, with younging direction toward the northwest; **d)** a contact between the Fabie pluton (bottom) and the basalt–andesite volcanic unit (top); **e)** brecciated clast within the Fabie pluton margin, a unit located close to a massive diorite body that likely caused brecciation when it intruded; **f)** a splay from the Baie Fabie shear zone located along Baie Magusi. Yellow line indicates the contact between two units.