Preliminary results from transect mapping in the Abitibi greenstone belt and Pontiac Subprovince, Rouyn-Noranda area, Quebec

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INTRODUCTION

This project is part of Metal Earth, a Canada First Research Excellence Fund, and government-, academia- and industry-sponsored research project that aims to explain the differential metal endowment of Archean greenstone terranes that have broadly similar geology. During the inaugural 2017 field season, Metal Earth initiated geological mapping and geophysical surveys along four ~40–80 km transects primarily located in the Abitibi Subprovince, specifically to address the question of metal endowment.

Fieldwork was carried out along the ~80 km Rouyn-Noranda (RN) transect in Quebec, which extends from ~2 km north of the Porcupine–Destor fault zone (PDFZ) and ~3 km east of Lac Dancës southeast through the city of Rouyn-Noranda before continuing south into the Pontiac Subprovince, where it ends ~22.5 km south of the Cadillac–Larder Lake fault zone (CLLFZ; Figure 1).

The purpose of the transect mapping is to collect geological data (lithological, structural, geochemical, geochronological, mineralization, alteration) and to compile previous work. By integrating newly acquired geological and geophysical data with historical data, each transect will produce a crust- and mantle-penetrating cross-section through the Abitibi greenstone belt. Eventually, the RN cross-section will be compared to other transects through equally or less-endowed greenstone belts.

The 2017 RN-transect mapping focused on two areas, for which little historical work exists relative to the exhaustive body of work available on the RN mining camp, the PDFZ and the CLLFZ. Transect area 1 (TA1; Figure 1) is located along the transect running north of the PDFZ and encompasses rocks of the 2722–2718 Ma Deguisier formation (DF) of the Kinojévis group (KG; Zhang et al., 1993; C.T. Barrie, unpublished report, 1999). Transect area 2 (TA2; Figure 1) extends from ~2 km north of the CLLFZ to the southern limit of the transect. Directly north and south of the CLLFZ are metavolcanic rocks belonging to the 2701 ±2 Ma Rouyn–Pelletier formation (RPF) of the Blake River group (BRG; Lafrance et al., 2005) and metasedimentary rocks of the <2677–2672 Ma Timiskaming Group (Davis, 2002), respectively. South of the Timiskaming Group metasedimentary rocks, the RN transect dominantly intersect a monotonous sequence of ca. 2682 Ma metasedimentary rocks of the Pontiac Subprovince (Mortensen and Card, 1993; Davis, 2002).

Rocks in the area have been regionally metamorphosed in the lower-greenschist to upper-amphibolite facies; however, the 'meta'- prefix has been omitted to improve the readability of the text. Mineral abbreviations follow Whitney and Evans (2010).

The main objective of the 2017 fieldwork in TA1 was to gain a better understanding of the DF volcanic strata, including minor felsic rock types. Fieldwork this summer included 1:10 000 scale mapping and sampling for petrographic, lithogeochemical and geochronological analyses. The results from this work will help in identifying the characteristics of the mantle source (depleted versus undepleted), establishing the compositional controls on the volcanic rocks (degree of partial melting of the mantle versus fractional crystallization), providing a framework for an intercomparison of those two attributes with other well-studied volcanic sequences of the Superior Province (intra-oceanic arc-like versus plume-like) and providing the first high-precision zircon U-Pb age for the DF in this area.

The primary goal for 2017 fieldwork in TA2 was to complete 1:10 000 scale mapping of the transect. Specific objectives related to mapping in this area included: 1) mapping the bedrock geology along the transect; 2) collecting samples for provenance, geochemical and geochronological studies; and 3) collecting new, and verifying previous, structural measurements. The results from this work will help to evaluate the current models for the structural development of the region (see Rehm et al., this volume), and to explore the usefulness of using trace-element lithogeochemistry and mineral chemistry to discriminate between different sedimentary successions.

This contribution also includes Summary of Field Work reports from a four-year Ph.D. and two two-year M.Sc. projects. These graduate projects are tied to the Metal Earth transect work and aim to address outstanding geological problems along the RN transect.

GENERAL GEOLOGY

Abitibi Greenstone Belt

The Abitibi greenstone belt (AGB), located in the Superior Province of Canada, extends from the Greenville Front in the Chibougamau area westward to the Kapuskasing structural zone. The belt constitutes a series of east-striking volcanic–sedimentary assemblages intruded by numerous plutonic suites. Following the nomenclature of Thurston et al. (2008), the AGB is divided into seven volcanic stratigraphic assemblages, based on similarity of age intervals, stratigraphy and geochemistry: an unnamed assemblage (>2750 Ma), the Pacaud assemblage (2750–2735 Ma), the Deloro assemblage (2734–2724 Ma), the Stroughton–Roquemaure assemblage (2723–2720 Ma), the Kidd–Munro assemblage (2719–2711 Ma), the Tisdale assemblage (2710–2704 Ma) and the Blake River assemblage (2704–2695 Ma). Overlying the volcanic assemblages are two sedimentary-rock–dominated assemblages: the Porcupine (Pontiac in Quebec) assemblage (2690–2685 Ma) and the Timiskaming assemblage (2677–2670 Ma), the latter representing the youngest supracrustal unit in the AGB (Corfu et al., 1991; Ayer et al., 2005).

Pontiac Subprovince

The Pontiac Subprovince, a granite and sedimentary rock domain situated at the southern margin of the Superior Province, is bounded to the north by the Abitibi Subprovince, to the southeast by the Proterozoic Grenville Province and to the west by the Paleoproterozoic Huronian Supergroup. Turbidites are the principal supracrustal rock type in the Pontiac Subprovince, which also includes thin ultramafic to mafic units (Camiré et al., 1993a, b; Davis, 2002). The volcanic rocks are interpreted as a structurally emplaced assemblage, with chemical characteristics similar to those of earlier volcanic rocks in the southern Abitibi Subprovince (e.g., Camiré et al., 1993b). The supracrustal rocks are intruded by several felsic plutons, e.g., the 2682 ±1 Ma Lac Fournière pluton (Davis, 2002), the 2679–2676 Ma Sladen intrusion (Helt et al., 2014; De Souza et al., 2015, in press) and the 2668–2663 Ma Decelles batholith (Mortensen and Card, 1993). The Pontiac Subprovince is of medium metamorphic grade near its northern contact with the AGB and increases to upper-amphibolite grade near the Decelles batholith.

Transect Area 1

The KG in Quebec overlaps in age range with the Stoughton–Roquemaure assemblage and the 2719–2717 Ma lower Kidd–Munro assemblage (Ayer et al., 2005). The Stroughton–Roquemaure assemblage is dominated by mid-ocean ridge basalt–like tholeiitic basalt, with komatiite and local felsic rocks, whereas the lower Kidd–Munro assemblage is dominated by felsic–mafic transitional to calcalkaline rocks (Ayer et al., 2002). The KG consists of two volcanic units: 1) the Lanaudière formation (LF), comprising basalt, andesite, rhyolite and komatiite, and considered equivalent to the lower part of the Kidd–Munro assemblage; and 2) the conformably underlying DF, consisting of mainly ferriferous and magnesian tholeiite, and considered to be part of the 2723–2720 Ma volcanic episode (Legault et al., 2006; Thurston et al., 2008). In TA1, the DF is a homoclinal sequence composed mainly of basalt that consistently youngs to the south and is moderately to steeply dipping to the south or north (Goutier, 2003). The PDFZ juxtaposes volcanic rocks of the DF (north) with rocks of the Hébécourt formation of the BRG (south). The latter is geochemically similar, but younger than the KG volcanic rocks (Goutier, 1997).

Transect Area 2

The RPF in TA2 is dominated by mafic to intermediate pillowed and massive flows with a tholeiitic affinity, and minor felsic volcaniclastic rocks of predominantly tholeiitic and locally transitional affinities (Ross et al., 2008; Moore et al., 2016). The RPF is limited to the south by the CLLFZ, where it abuts against mainly polymictic conglomerate and lesser wacke of the Granada formation of the Timiskaming Group. Seismic evidence indicates that the Abitibi and Pontiac subprovinces are structurally juxtaposed along a north-dipping, south-vergent thrust zone (Benn et al., 1994). However, the contact between the Timiskaming assemblage and the Pontiac group sedimentary rocks is inferred to be an angular unconformity, based on steeper subvertical bedding in the latter (Holubec, 1972). The Pontiac group is largely composed of kilometre-scale, turbiditic greywacke successions (Camiré et al., 1993a).

RESULTS OF SUMMER FIELDWORK

Deguisier Formation, Transect Area 1

Mafic to intermediate volcanic rocks comprise about 80% of the DF in TA1 in the map area. Gabbroic sills cover about 15% of the area, including one dioritic–tonalitic sill. The remaining ~5% of the map area is represented by a ~50–100 m thick felsic volcanic unit, with a kilometre-scale strike length. The felsic volcanic unit is associated with <30 cm thick intercalated beds of banded iron formation (BIF).

Mafic to Intermediate Volcanic Rocks

Mafic to intermediate volcanic rocks dominate the map area and are generally mesocratic, grey green, fine to medium grained and aphyric. Determined from hand samples, the mineral assemblage typically consists of Pl-Chl-Ep-Qz±Mag±Ilm±Act±Cal±Py. Locally, the volcanic rocks are amygdaloidal, containing up to ~10% carbonate- and/or quartz-filled amygdules that are ~3-5 mm in diameter. Deformation and development of a structural fabric is negligible, with the exception of one outcrop near the PDFZ, and most primary volcanic textures are preserved. Pillowed flows are common, exceptionally well preserved and consistently indicate a younging direction toward the south. Pillows are generally medium to large (~0.3–3 m), with pillow selvages <1–3 cm thick (Figure 2a). Locally, the pillows show radial and concentric cooling fractures. Massive units are common but the rarity of exposed contact relationships with nearby pillowed flows makes it difficult to interpret whether they represent high-level sills or massive flows. Brecciated mafic volcanic rocks are relatively uncommon but are found in close spatial association with pillowed mafic volcanic flows. The breccia is characterized by a well-preserved jigsaw-fit texture, with minor rotation of clasts, or subangular pillow fragments in a mesocratic grey, aphanitic matrix (Figure 2b). Breccia with dominantly granular-sized, angular fragments in a quartz-rich matrix were also observed (Figure 2c). Moderately to strongly pervasive chloritization±silicification is ubiquitous in the volcanic rocks, with little to no primary mineralogy preserved. Rare localized epidote patches, typically in pillow interiors, and randomly oriented epidote-quartz veins were also observed. No obvious mineralization was observed in these rocks.

At a larger exposure of mafic pillowed flows, the pillows appear to truncate delicate tuff beds that occur as ~20–40 cm thick isolated beds, with a strike length of ~0.5–1 m. The beds are subvertical and consistently display an overall east orientation, which suggests that they might represent primary bedding (Figure 2d).

Felsic Volcanic Rocks and Banded Iron Formation

One thin unit of aphyric, felsic volcanic rocks is located just north of the planned RN transect but was included in the geological transect mapping because it is distinctive and offers an opportunity for age dating. The felsic volcanic rocks are thinly to medium-bedded, fine- to coarse-grained tuff and tuff breccia (Figure 3a, b). The contact relationship with the mafic to intermediate volcanic rocks is not exposed but the bedding orientation is parallel to that inferred for the mafic pillowed flows. In one location, the felsic tuff is in sharp contact with a gabbroic sill, with chilled margins at the contact (Figure 3c). A narrow ~10 cm contact aureole in the felsic tuff is characterized by a pale green colouration and conchoidal fracture when hit with a hammer (Figure 3c). The felsic tuff is yellow to yellow brown, fine to coarse grained (<2 mm particles) and locally displays vague, normal graded beds, indicating a younging direction toward the south. Strike measurements range from 255 to 270° (right-hand rule) with dips of ~60–70°, indicating that the strata are overturned. The tuff breccia consists of lapilli- to block-size clasts composed of melanocratic grey chert and bedded tuff similar to that described above (Figure 3b). The matrix is fine to medium grained, but on average is coarser than the felsic tuff. The felsic volcanic rocks show no indication of alteration. A narrow (~10–20 cm) sulphidic interval was observed at one location, with significant amounts of pyrite (~10–25%), but otherwise no indication of mineralization was observed in this unit.

In one location, a thinly laminated BIF (Figure 3d) is spatially associated with the felsic tuff but is potentially separated from it and hosted by a more mafic unit. The BIF is composed of alternating bands of magnetite and dark red jasper, and forms a semicontinuous unit parallel to bedding in the nearby felsic tuff. Poor outcrop quality locally obscured the relationship between the BIF and the felsic tuff.

Mafic to Intermediate Intrusions

The volcanic rocks are intruded by gabbroic, dioritic and tonalitic sills. Gabbroic sills form ~50–400 m thick, melanocratic grey to black, medium- to coarse-grained units, with a mineral assemblage consisting of Hbl-Pl-Mag±Cpx±Py. They are characterized by a relatively high magnetic susceptibility compared to the volcanic rocks. Clear crosscutting relationships were established with the felsic tuff but not with the mafic volcanic rocks. Less abundant dioritic–tonalitic sills form 10–200 m thick, mesocratic grey to pale green, medium- to coarse-grained units, with a mineral assemblage consisting of Pl-Hbl-Qz and maybe Ttn.

Pontiac Subprovince, Transect Area 2

The majority of TA2 transects the Pontiac Subprovince and only ~2 km (~8%) is located in the Abitibi Subprovince (Figure 1). In the Pontiac Subprovince, TA2 consists of ~85% sedimentary rocks, ~10% intermediate to felsic intrusions, and ~5% amphibolite and mafic dykes. In the Abitibi Subprovince, TA2 intersects predominantly volcanic rocks and ~5% gabbroic intrusive rocks. The Abitibi Subprovince rocks are not discussed in this contribution.

Sedimentary Rocks

The Pontiac group sedimentary rocks are fine- to medium-grained, leuco- to mesocratic grey and are essentially ±St±Grt-Bt schist composed of 0–2% St, 0–5% Grt, 5–40% Bt and 60–95% Qz > Fsp (Figure 4a). Pyrite is present in trace amounts to ~1%. Outcrop exposures are typically leuco- to mesocratic grey on least weathered surfaces and increasingly yellowish, brownish to orangey on more weathered surfaces. Primary bedding is defined by changes in the ratio of biotite to leucocratic minerals (Figure 4a, b). Locally, normal graded bedding can be used to infer the younging directions (Figure 4b), but commonly the graded bedding is poorly preserved and younging directions are often of low confidence. Bedding orientation is generally southwest-trending, with steep dips to the north or moderate dips to the south; however, whether changing dip directions systematically accompany younging reversals remains uncertain because of poorly preserved, or lack of, younging indicators. Garnet porphyroblasts sometimes increase in modal abundance in the biotite-rich layers and can be used to infer the younging direction. Crossbedding was observed at one location (Figure 4c). The sedimentary beds are generally medium in thickness (10–30 cm) but locally bedding was not observed. Overall, the Pontiac group sedimentary rocks are very monotonous. Alteration is in general insignificant but at the contact with the overlying Timiskaming assemblage, pervasive carbonate alteration is moderate to intense and locally associated with quartz veining (Figure 4d). No mineralization was observed in the Pontiac group.

The Timiskaming Group conglomerate overlies the Pontiac group sediments; however, the contact relationship is not exposed. The conglomerate is generally polymictic, with clasts of several different rock types that range in composition from felsic to mafic. Near the southern contact, a couple of outcrops appear to be monomictic, with clasts of medium- to coarse-grained granitoid rock (Figure 4e). The felsic to intermediate granitoid clasts are typically subrounded, whereas other clasts, such as ultramafic to mafic clasts, are strongly flattened. The matrix is generally fine to medium grained, mesocratic grey and composed of mainly quartz and feldspar, ~5–15% biotite±amphibole and ~1% pyrite. The clast to matrix ratio varies from ~1:10 to ~4:1, but bedding defined by this variability was not observed. The clast size ranges from very coarse pebble to medium boulder, but also did not appear to define bedding at any individual outcrop. Toward the CLLFZ, the Timiskaming Group consists of wacke very similar in appearance to the Pontiac group sedimentary rocks, but only locally showing well-defined bedding (Figure 4f). A schist consisting of ±Bt-Tlc-Chl can be seen in an outcrop within the wacke (Figure 5). This unit is melano- to mesocratic grey, fine to medium grained, with a moderately soapy feel. Carbonate alteration is ubiquitous in the Timiskaming Group sedimentary rocks of TA2 and occurs as veins or is moderately to intensely pervasive. Locally, carbonate alteration is observed in the strain shadows of rotated clasts (σ-type porphyroclasts) in the conglomerate. On weathered surfaces, orangey to buff carbonate alteration is clearly visible. No mineralization was observed in the Timiskaming Group.

Intrusions

Felsic to intermediate intrusive rocks were observed in the southern part of TA2, where they intrude the Pontiac group sedimentary rocks. A white to pale pink, medium- to very coarse grained granodiorite to tonalite, with ~2–-4% muscovite and locally 1–3% garnet, is the dominant intrusion. A smaller leucocratic pink, coarse-grained, massive granitic intrusion forms a subrounded, 200 by 300 m surface expression ~6 km north of the southern start of the transect. A leucocratic grey, medium- to coarse-grained monzodiorite outcrop occurs ~6 km south of the contact between the sedimentary rocks of the Pontiac and Timiskaming groups. A few massive gabbroic dykes locally outcrop along the transect and were observed to crosscut the felsic intrusions.

Amphibolite

An amphibolite unit is exposed at one location along the transect and appears to fall on the southwestward trend of the ultramafic to mafic volcanic belt (see Rehm et al., this volume). The amphibolite is melano- to mesocratic grey, fine to medium grained, strongly foliated with a mylonitic texture (Figure 6a) and appears to be intercalated with a ~10 cm band of biotite-schist, similar in mineralogy to the sedimentary rocks of the Pontiac group (Figure 6b). The orientation of the biotite-schist is parallel to the main foliation fabric. Weak to moderate alteration consists of chlorite veins associated with pyrite stringers and disseminated grains.

Structural Geology

In general, the degree of deformation is minimal in TA1. Rocks in the area have well-preserved primary features and show no obvious tectonic fabrics. Only the regional tilting indicates that deformation has taken place. However, at the southern margin of TA1, there is a strong foliation and slickenline lineation associated with the east-trending crustal-scale PDFZ. The slickenlines, along with a weak S-C fabric, suggest a dextral strike-slip movement (Figure 7a). Faulting and major lithological offsets are not obvious based on field observations alone because of the monotonous volcanic stratigraphy. However, the offset of linear magnetic anomalies in the regional airborne magnetic geophysical data (Ministère des Ressources naturelles et de la Faune, 2017) indicate the presence of minor approximately north-trending faults.

In TA2, the Pontiac group sedimentary rocks are strongly deformed. Despite generally well-preserved primary bedding in the Pontiac group sedimentary rocks, relatively few of these clearly indicate the direction of younging in the strata. Nevertheless, younging reversals can be inferred occasionally by graded bedding alone. The earliest deformational fabric observed is a bedding-parallel cleavage (S_1) defined by oriented biotite (Figure 4a). The S_1 fabric was not observed to be axial planar to any folds in the area, but appears to have been folded along with the bedding during the formation of a later generation of structures. A second, weakly to moderately developed and locally penetrative biotite cleavage (S_2) generally overprints S_{0-1} in a clockwise fashion at low angles (<20°; Figure 4a) but locally also counterclockwise. Whether the change in the S_{0-1} and S_2 rotational relationship coincides with younging reversals is not always clear. Locally, the S_2 cleavage is observed to be axial planar to tight, outcrop-scale F_2 folds (Figure 7b). A crenulation cleavage is locally observed in places where no bedding was clearly defined (Figure 7c). The angle between the principle cleavage and the crenulation cleavage is typically higher (>20°) than the angle commonly observed between S_{0-1} and S_2. Furthermore, the crenulation cleavage typically strikes north, is moderately to steeply dipping and oriented counterclockwise to the principle cleavage. At this stage, it is unclear whether the crenulation cleavage is another manifestation of the S_2 fabric or if it occurred later.

In the Timiskaming Group sedimentary rocks, no well-defined bedding measurements were recorded. The dominant foliation fabric is defined by biotite and has the same general east-striking orientation and northerly dip as that observed in the Pontiac group sedimentary rocks. A crenulation cleavage was only observed in the ±Bt-Tlc-Chl schist (see above; Figure 5) and shows similar characteristics as the crenulation cleavage described in the Pontiac group sedimentary rocks. Locally, a mineral lineation (Figure 7d) is associated with the dominant fabric in the conglomerate plunging moderately to the west-northwest and subparallel to a stretching lineation defined by the clast shape. Shear-sense indicators in conglomerate primarily consist of σ- and δ-type porphyroclasts but are rarely associated with a high level of confidence. In sections viewed approximately parallel to the mineral lineation and perpendicular to foliation, the rotated clasts appear to suggest north-side down, south-side up, oblique-slip normal movement (Figure 7e). A similar relative shear-sense movement is inferred from slickenlines (Figure 7f).

CONCLUSIONS AND FUTURE WORK

Mapping at 1:10 000 scale was conducted in the Rouyn-Noranda area along parts of a ~80 km transect extending from north of the PDFZ in the Abitibi Subprovince, to south of the CLLFZ and into the Pontiac Subprovince. Data were collected from predominantly two segments, TA1, north of the PDFZ, and TA2, a segment transecting the Pontiac Subprovince.

Observations in TA1 documented an east-trending and relatively undeformed stratigraphy, dominated by a homoclinal, south-facing succession of mafic to intermediate pillowed and massive flows. A relatively narrow felsic volcanic tuff and tuff breccia unit associated with minor BIF represents the only break in the thick extrusive sequence of mafic to intermediate volcanic rocks. The presence of intercalated pyrite-rich beds was noted locally within the felsic volcanic unit.

Sedimentary rocks of the Pontiac Subprovince are generally strongly deformed, showing evidence of at least two generations of ductile deformation. Nonetheless, the stratigraphy maintains an overall east–west orientation. The Pontiac group consists of monotonous wacke, whereas the Timiskaming Group in the area is more variable, consisting of both wacke and polymictic conglomerate. A noteworthy change within the Pontiac group sedimentary rocks is the presence of an amphibolite unit that is contiguous with a southwest-trending volcanic belt of ultramafic–mafic rocks. The emplacement mechanism of the volcanic rocks is currently under investigation near Lac Bellecombe, west of TA2 (see Rehm et al., this volume). Here the amphibolite unit appears to be intercalated with what could prove to be Pontiac group sedimentary rocks. Another noticeable unit of modest dimensions occurs within the Timiskaming Group sedimentary rocks and consist of ±Bt-Tlc-Chl schist that could represent the ca. 2710 Ma Piché group of variably deformed and carbonatized ultramafic and mafic volcanic rocks (Pilote et al., 2015). The contact zone between the sedimentary rocks of the Timiskaming and Pontiac groups is characterized by moderate to intense pervasive carbonate alteration.

Future work will consist of petrographic, geochemical and geochronological analyses of samples collected this summer. Compilation of historical data will proceed and by integration with observations from this year, including geophysical data, the construction of a Rouyn-Noranda cross-section will be initiated.

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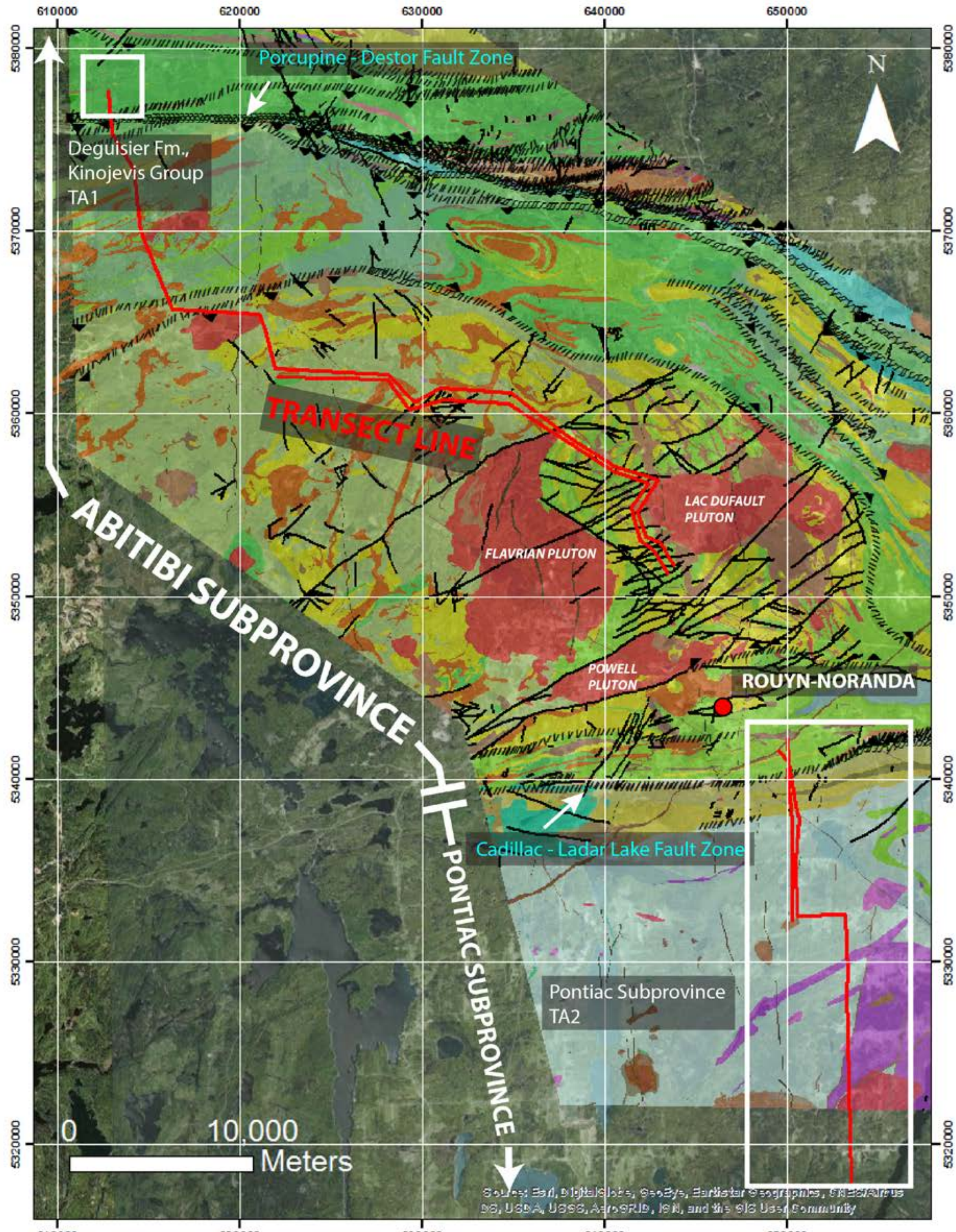

Figure 1. Regional geology of the Noranda area showing the transect (red lines) and transect areas (white boxes) in the Rouyn-Noranda area. The Abitibi Subprovince is dominated by volcanic supracrustal rocks (shades of green and yellow) and granitoid intrusions (red). The Pontiac Subprovince is dominated by supracrustal sedimentary rocks (pale blue) and minor mafic (green) and ultramafic (purple) volcanic rocks (modified from Ministère des Ressources naturelles et de la Faune, 2017). Abbreviation: Fm., formation; TA, transect area.

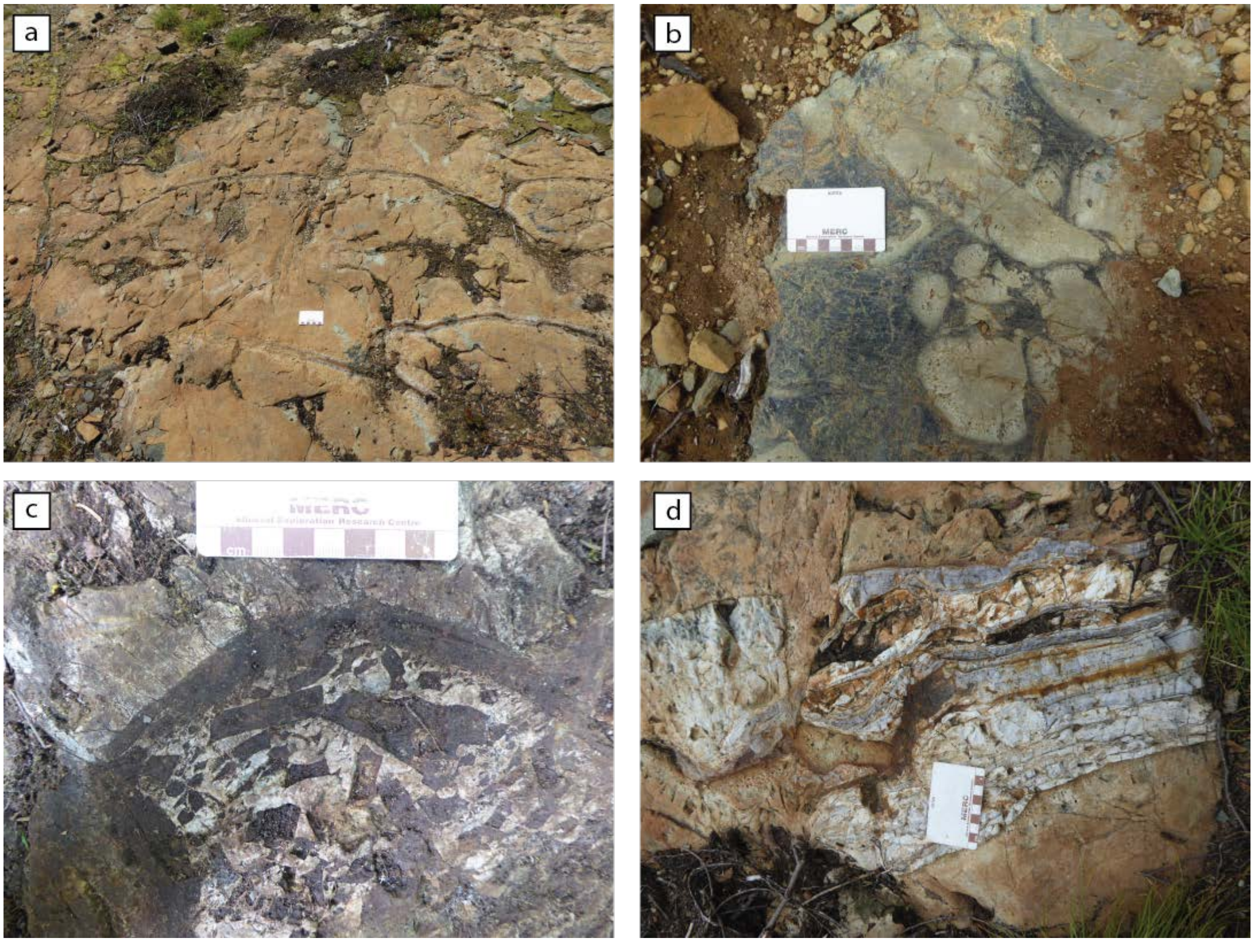

Figure 2. Outcrop photographs from the study area in the Abitibi greenstone belt, showing **a)** an example of well-preserved pillows in the Deguisier formation; **b)** pillow breccia with jigsaw-fit textures; **c)** breccia with granular-sized angular fragments in a quartz-rich matrix; **d)** delicate tuff beds, possibly representing primary bedding despite being truncated by pillowed flows.

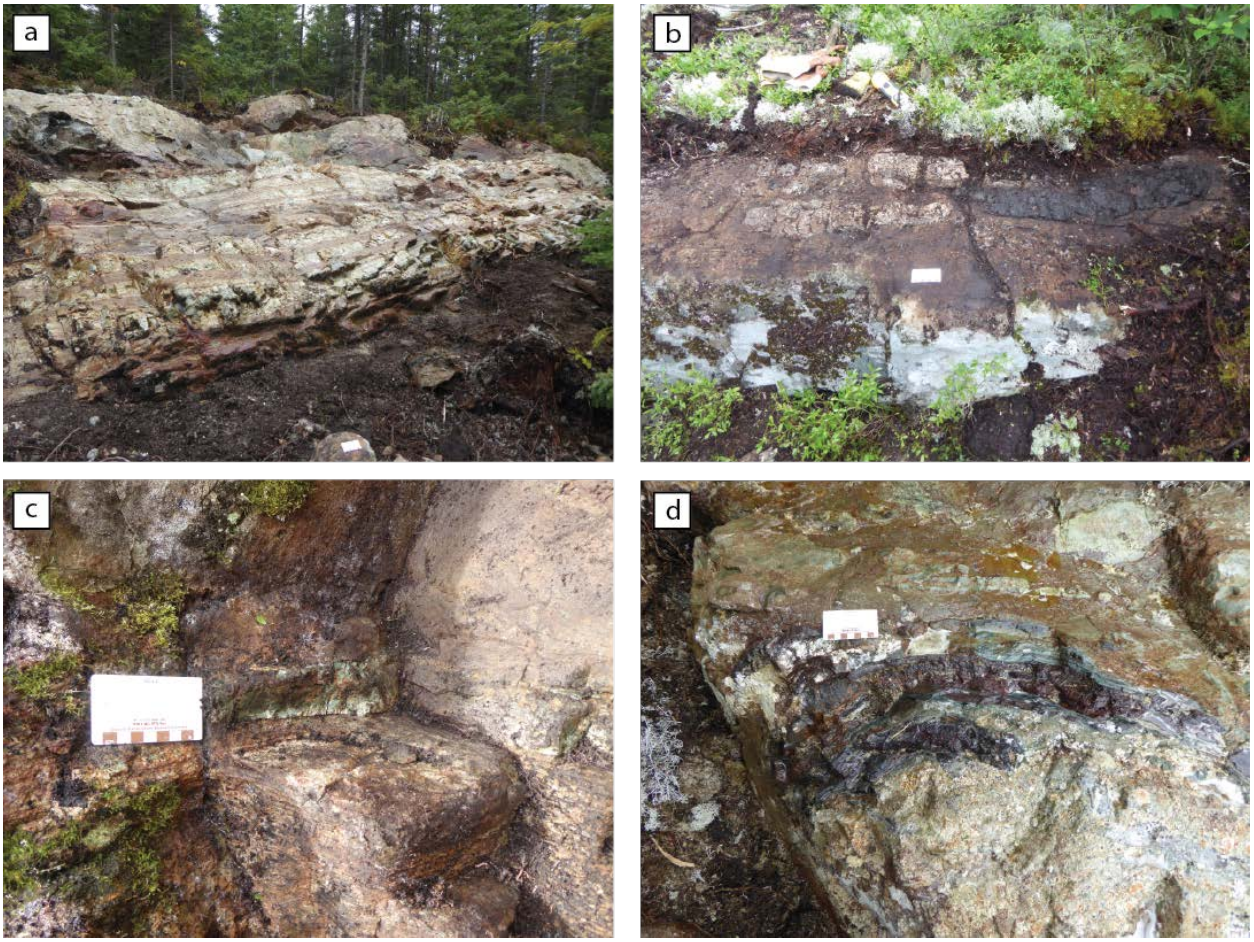

Figure 3. Outcrop photographs from the study area in the Abitibi greenstone belt, showing **a)** thinly to medium-bedded and fine-grained tuff; **b)** tuff breccia with clasts of bedded tuff and chert (dark grey); **c)** a pale green contact aureole in the felsic tuff at the contact with a gabbroic sill; **d)** felsic tuff, at the same location as a), spatially associated with a thinly laminated banded iron formation that forms a semicontinuous unit parallel to the bedding in the tuff (the contact relationship between the two units is still unclear).

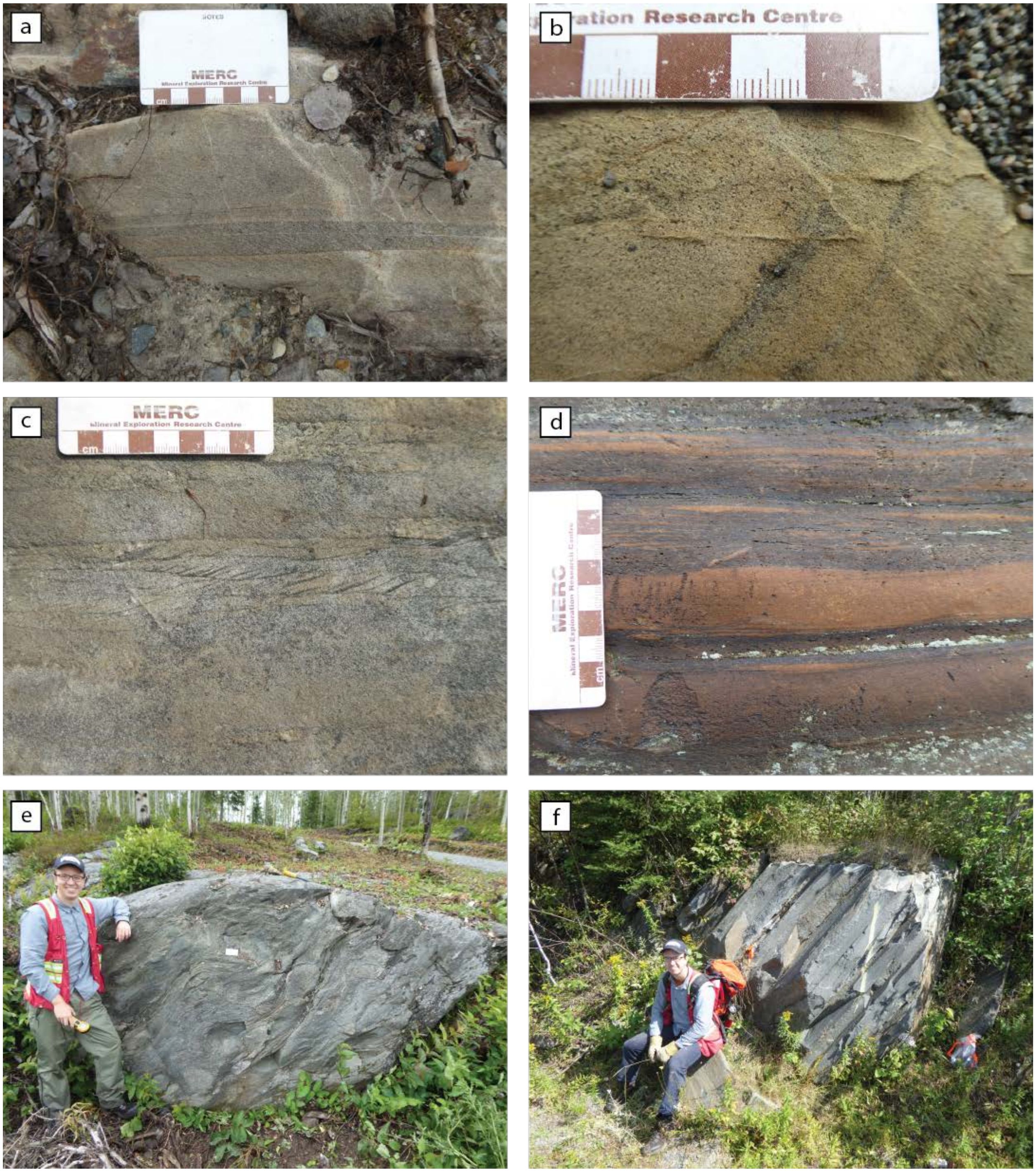

Figure 4. Outcrop photographs from the study area in the Abitibi greenstone belt, showing **a)** a typical Pontiac group sedimentary rock, the fabric of which is clockwise to bedding and overprints an earlier bedding-parallel foliation; **b)** graded bedding in the Pontiac group sedimentary rocks interpreted to indicate younging to the right in the photo; **c)** a rare example of crossbedding in the Pontiac group sedimentary rocks indicating younging toward the top of the photo; **d)** pervasive-style carbonate alteration in the Pontiac group sedimentary rocks near the contact with the Timiskaming Group sedimentary rocks; **e)** Timiskaming Group conglomerate with a clast population at this location dominated by granitoid rocks; **f)** Timiskaming Group sedimentary rocks, very similar in appearance to the Pontiac group sedimentary rocks.

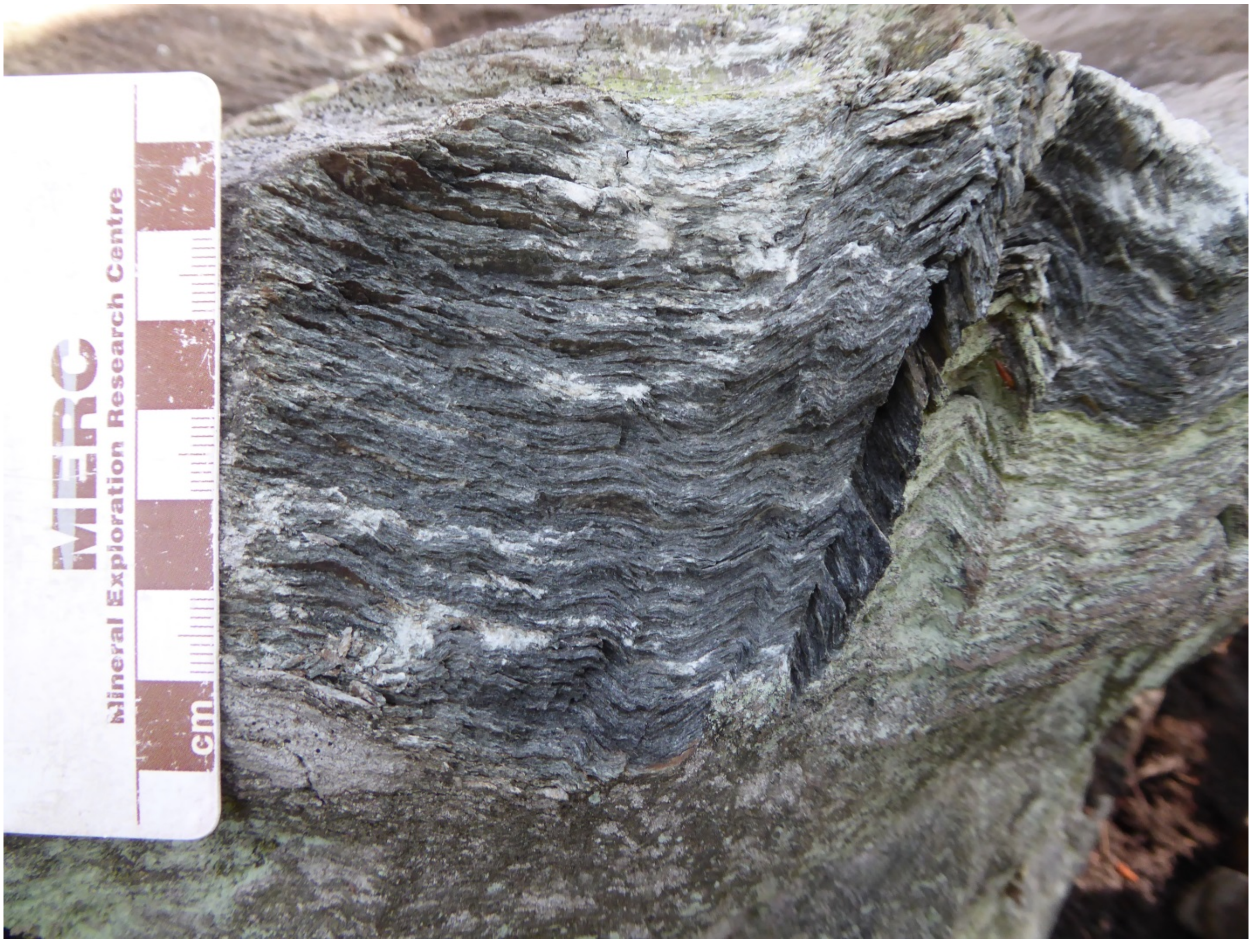

Figure 5. Outcrop photograph from the study area in the Abitibi greenstone belt, showing schist consisting of ±Bt-Tlc-Chl hosted within the Timiskaming Group sedimentary rocks. Note the crenulation cleavage oriented approximately from the bottom to the top in the photograph.

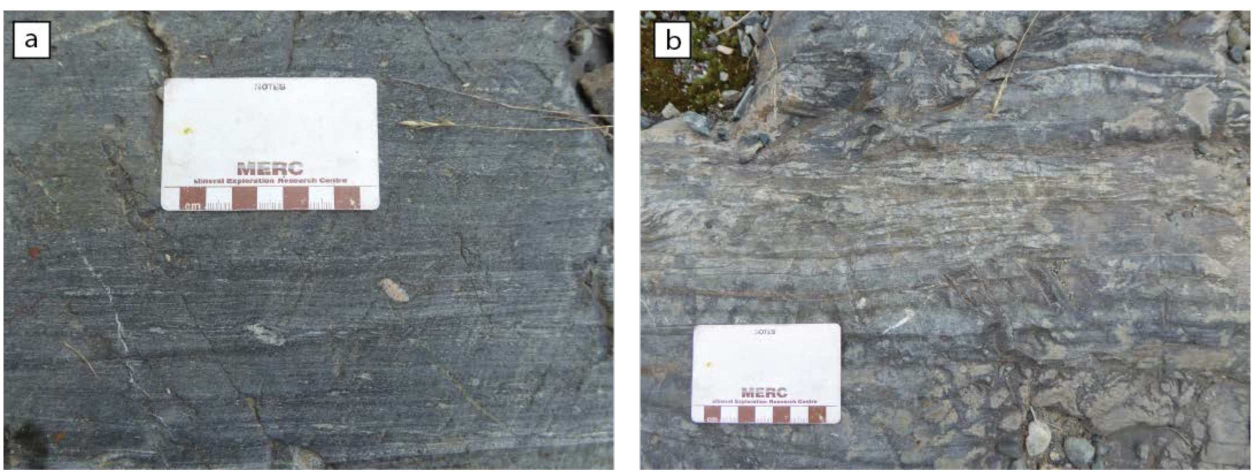

Figure 6. Outcrop photographs from the study area in the Abitibi greenstone belt, showing **a)** an amphibolite unit with a strong foliation fabric and porphyroclasts of more felsic material; **b)** an intercalated felsic unit (lighter band in the central part of the photo) oriented from left to right in the photo.

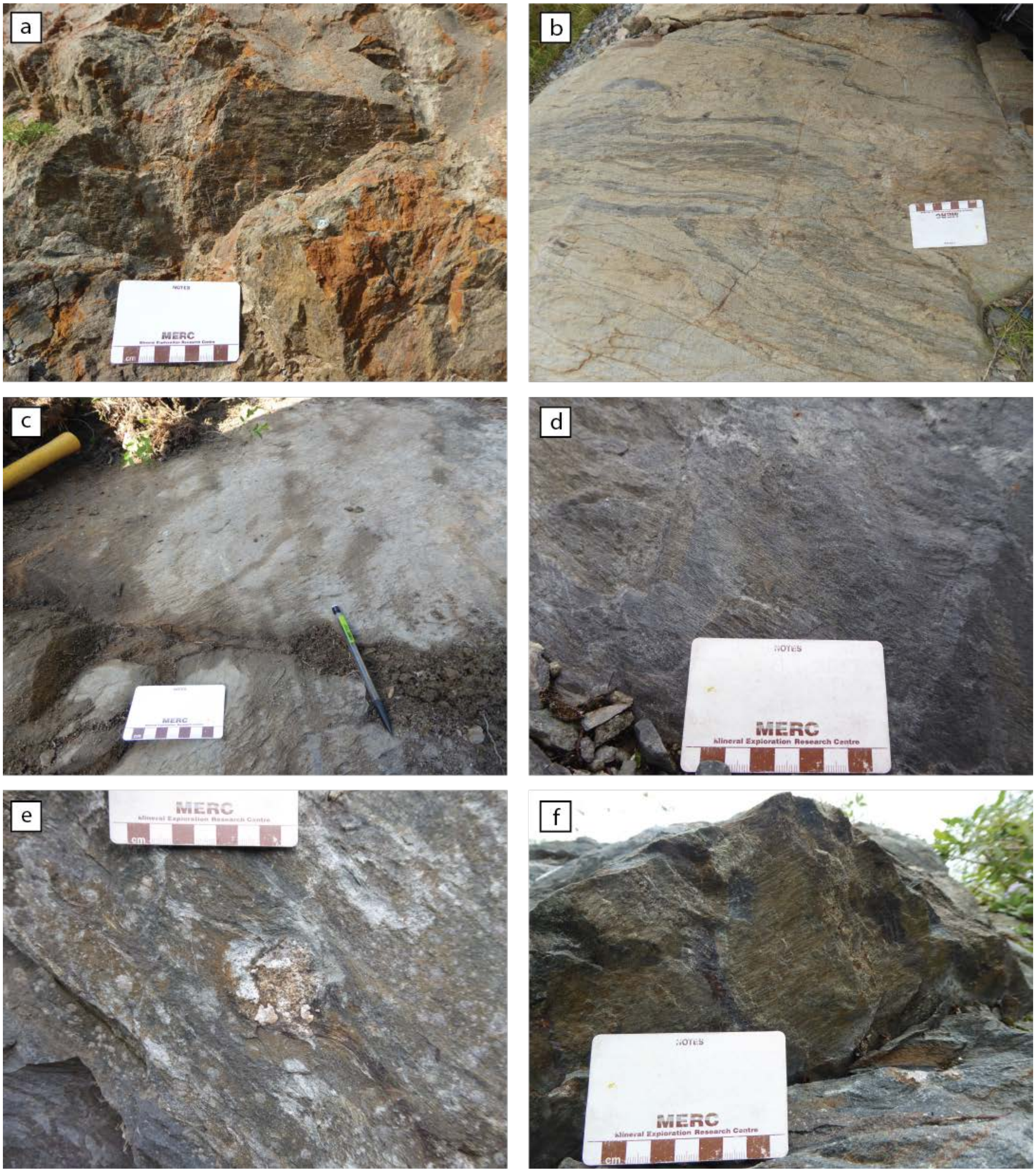

Figure 7. Outcrop photographs from the study area in the Abitibi greenstone belt, showing **a)** strongly deformed and carbonate-altered volcanic rock near the Porcupine–Destor fault zone, with subhorizontal slickenlines indicating a dextral strike-slip movement; **b)** F_2 folds in the Pontiac group sedimentary rocks; **c)** crenulation cleavage in the Pontiac group sedimentary rocks oriented parallel to the pencil; **d)** mineral lineation in the Timiskaming Group conglomerate, which appears to be subparallel to the stretching lineation defined by clasts in the conglomerate; **e)** δ-type porphyroclasts in the Timiskaming Group conglomerate indicating north-side down (right side of photo), south-side up, oblique-slip normal movement; **f)** slickenlines in the Timiskaming Group conglomerate that appear to indicate a similar shear-sense movement as in e).