Stratigraphic and Structural Investigations near Major Deformation Zones in the Malartic Transect Area, Southern Abitibi and Pontiac Subprovinces, Quebec

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INTRODUCTION

The Superior Province is the largest exposed Archean craton. It hosts numerous world-class volcanogenic massive sulfide (VMS) and gold deposits, as well as less common magmatic nickel-copper deposits (Lydon, 2007). Most mineral deposits exhibit a close spatial relationship to east-southeast–striking deformation zones of regional to crustal scale, namely the Larder Lake–Cadillac deformation zone (LLCDZ) and Porcupine–Destor–Manneville deformation zone (PDMDZ). During the summer of 2018, detailed geological mapping was carried out near these major deformation zones or faults in the metal-endowed Malartic transect area to determine the stratigraphic setting and structural controls on mineralization along the transect.

REGIONAL GEOLOGICAL SETTING

The Malartic transect is a geological–geophysical traverse roughly 100 km long, trending north across Neoarchean volcanic-granitoid terranes and sedimentary basins of the southern Abitibi and Pontiac subprovinces. The Abitibi Subprovince is marked by seven volcanic stratigraphic episodes (Thurston et al., 2008) based on similarity of age intervals, stratigraphy and geochemistry (Figure 1): <2750 Ma (unnamed assemblage), 2750–2735 Ma (Pacaud assemblage), 2734–2724 Ma (Deloro assemblage), 2723–2720 Ma (Stoughton–Roquemaure assemblage), 2719–2711 Ma (Kidd–Munro assemblage), 2710–2704 Ma (Tisdale assemblage) and 2704–2695 Ma (Blake River assemblage). In the Malartic transect area (Figures 2, 3), the Deloro assemblage is represented by the ca. 2727 Ma (Labbé, 1999) Landrienne group, which is composed mainly of mafic to intermediate volcanic and volcaniclastic rocks, with minor felsic volcanic rocks and sedimentary rocks. The 2720–2716 Ma (Pilote et al., 2015) Kinojévis group consists chiefly of mafic to intermediate volcanic and volcaniclastic rocks, with minor gabbro sills, ultramafic rocks and felsic volcanic flows, and corresponds to the Kidd–Munro assemblage. The ca. 2714 Ma (Labbé, 1999) Lac Arthur group consists predominantly of intermediate to mafic volcanic rocks, with minor felsic volcanic rocks, and is equivalent to the Kidd–Munro assemblage. The 2714–2704 Ma (Pilote et al., 1999) Malartic group consists mainly of komatiite and basalt, and corresponds to the upper Kidd–Munro assemblage and Tisdale assemblage. The ca. 2706 Ma (Pilote et al., 2014) Piché group includes ultramafic to mafic intrusions and schists, with minor felsic volcanic rocks and sediments, and is equivalent to the Tisdale assemblage. The ca. 2704–2702 Ma (Pilote et al., 1998) Louvicourt group comprises mafic to intermediate volcanic rocks and minor intermediate to felsic volcaniclastic rocks, and is equivalent to the lower Blake River assemblage.

The Malartic transect comprises five metasedimentary groups: the <2691–2685 Ma Kewagama group (Feng and Kerrich, 1991; Davis, 2002), composed chiefly of mudstone and wacke typical of a turbidite sequence; the <2685 Ma Cadillac group (Davis, 2002), consisting largely of turbiditic siltstone and wacke, with minor biotite-chlorite-actinolite schist and felsic volcaniclastic rocks; the <2685–

2682 Ma Pontiac group (Davis, 2002), consisting mainly of mudstone and wacke, with minor iron formation and conglomerate (Gunning and Ambrose, 1940; Goulet, 1978; Dimroth et al., 1982); the <2677–2672 Ma Timiskaming Group (Davis, 2002; Pilote et al., 2015), composed of crossbedded siltstone and sandstone, and polymictic conglomerate; and the <2698 Ma Chicobi group (Ayer et al., 2002), comprising mudstone, crossbedded sandstone and polymictic conglomerate. Several plutons cut across both volcanic assemblages and sedimentary groups, including the ca. 2682 Ma Lac Fournière (Davis, 2002), ca. 2681–2660 Ma Preissac (Ducharme et al., 1997), ca. 2680–2640 Ma La Corne (Machado et al., 1991) and ca. 2647–2642 Ma La Motte (Machado et al., 1991; Ducharme et al, 1997) plutons.

FIELD GEOLOGY

For convenience, the Malartic transect area is divided into six tectonostratigraphic domains including, from north to south, the Chicobi, Kinojévis–Lac Arthur, Manneville, Preissac–Vassan, Cadillac–Rivière Héva and Pontiac domains. They are described below, with emphasis on new findings about contact relationships between important units.

Chicobi Domain

The Chicobi domain consists of east-striking mafic volcanic rocks of the Desboues formation, Lac Arthur and Béarn groups, and sedimentary rocks of the Chicobi sedimentary basin. The latter is bounded by the east-striking northern section of the Chicobi fault and the Castagnier fault. The chronology of volcanism and sedimentation in this domain is not well constrained due to the lack of geochronological data. The basin contains foliated turbiditic mudstone and sandstone, with minor banded magnetite-chert iron formation and hematite-jasper iron formation, and conglomerate. A large syenite intrusion and gabbroic dikes cut across the basin and surrounding volcanic rocks. Mapping this past summer revealed the presence of a new polymictic, clast-supported, conglomeratic unit unconformably overlying pillowed basalt of the Desboues formation and crossbedded sandstone of the Chicobi group (Figure 4a). The conglomerate contains clasts of various rock types, including basalt, gabbro, orthogneiss, felsic volcanic rock, granitoid clasts, magnetite-chert iron formation and sandstone. The Chicobi basin and surrounding volcanic rocks were affected by multiple generations of structures. The most penetrative fabric is a northwest-striking subvertical cleavage (Figure 4b), which is generally clockwise or subparallel to bedding and lithological contacts. Multiple veins pinch and swell parallel to this cleavage and were emplaced either before or during the formation of the cleavage. A stretching lineation defined by aligned amphibole, biotite and elongated granitoid clasts extends along the main cleavage and plunges steeply to the northwest (Figure 4c). Asymmetrical strain shadows around granitoid clasts suggest a south-side-up sinistral movement along the northern Chicobi fault (Figure 4b, c). Late Z-shaped folds overprint the main cleavage (Figure 4d) and likely formed during dextral shearing. Conjugate sets of kink bands and a north-striking, subvertical, cataclastic fault breccia crosscut all other structures.

Kinojévis–Lac Arthur Domain

The Kinojévis–Lac Arthur domain is located north of the Northern Manneville fault. It is divided into several dominantly volcanic terranes (from oldest to youngest): the ca. 2727 Ma (Labbé, 1999) Landrienne group, 2720–2716 Ma (Pilote et al., 2014) Kinojévis group, Figuery group, Amos group, La Morandière group and ca. 2714 Ma (Labbé, 1999) Lac Arthur group. These terranes are intruded by several felsic plutons, namely the Berry, Trécesson, Amos, Duverny and Claverny plutons. The volcanic rocks are folded by a series of west-striking, upright, tight regional folds with an axial planar cleavage. Late, north-striking and upright open folds and kink bands overprint the cleavage. A new U-Pb zircon age

of ca. 2716 Ma was obtained from a thin dacite sliver of the Figuery group (M. Hamilton, pers. comm., 2018), which therefore correlates with the Kidd–Munro assemblage.

Manneville Domain

The Manneville domain is located between the Northern and Southern Manneville fault zones. It consists of the volcanic La Motte–Vassan formation of the Malartic group and sedimentary Caste formation (formerly known as the 'Lac Caste group') of the Kewagama group. These volcano-sedimentary rocks are intruded by three major plutons, the Preissac, La Corne and La Motte plutons. A new monomictic, matrix-supported conglomerate unit was found at the contact between the sedimentary Caste formation and the Malartic group. This conglomerate contains clasts of ultramafic schist and less deformed ultramafic rocks, and is younging toward the ultramafic rocks to the south, which suggests the presence of a fault contact between the older volcanic Malartic group and the younger sedimentary Caste formation. A new igneous zircon age of ca. 2708 Ma was obtained from a mafic tuff-breccia unit with felsic fragments of the La Motte–Vassan formation (M. Hamilton, pers. comm., 2018), which is younger than a previously reported U-Pb age of ca. 2714 Ma (Pilote et al., 1999) from a felsic volcaniclastic unit at lower stratigraphic levels of this formation.

The Northern Manneville fault is interpreted as the eastern extension of the Porcupine–Destor fault. It strikes west, dips moderately to the north and has a down-dip biotite-amphibole lineation. The σ-type porphyroclasts and deflection of foliation suggest a north-side-up reverse movement. The Southern Manneville fault is interpreted as a splay of the Porcupine–Destor fault. The main foliation along the fault is axial planar to northwest-striking, isoclinal to tight, upright folds, which plunge to the east parallel to a stretching lineation defined by aligned plagioclase, amphibole and biotite. A biotite granitic dike is isoclinally folded and overprinted by the foliation. It yielded an igneous zircon age of ca. 2680 Ma (M. Hamilton, pers. comm., 2018), which provides a maximum age limit for the formation of the foliation. Another granitoid dike with mafic foliated and nonfoliated xenoliths yielded inherited zircon ages of ca. 2709 Ma, ca. 2703 Ma and ca. 2693 Ma (M. Hamilton, pers. comm., 2018). Late, northeast-striking, tight to open upright folds with an axial-planar crenulation cleavage overprint the main foliation.

Preissac–Vassan Domain

The Preissac–Vassan domain is located between the Southern Manneville and Rivière-Héva fault zones. It consists of ultramafic–mafic metavolcanic rocks of the Malartic group and various felsic intrusive phases of the Preissac and La Corne plutons. The paucity in outcrop precluded further investigations and the map pattern is largely based on aeromagnetic data.

Cadillac–Rivière-Héva Domain

The Cadillac–Rivière-Héva domain is located between the Larder Lake–Cadillac deformation zone and the Rivière-Héva fault zone. It consists of ultramafic to mafic metavolcanic rocks of the Malartic and Piché groups, felsic and mafic metavolcanic rocks of the Louvicourt and Blake River groups, and metasedimentary rocks of the southern Abitibi basins (Mont-Brun formation and Cadillac group). Previous studies suggest either depositional contacts (e.g., Gunning and Ambrose, 1940; Imreh, 1984) or fault contacts (e.g., Desrochers and Hubert, 1996) between those units. A northeastward-younging conglomerate, containing clasts of the underlying Piché metavolcanic rocks, was found at the base of the Cadillac group sedimentary basin, suggesting that the contact is an erosional unconformity (Figure 5a, b). The contact is overprinted by a west-northwest-striking subvertical cleavage and steep east-plunging stretching lineation, which are axial planar and coaxial, respectively, to regional folds in the Cadillac group basin (Figure 5c). Asymmetrical strain shadows around the granitoid clasts suggest Piché

metavolcanic rocks moved upward with respect to the conglomerate of the Cadillac group basin (Figure 5d). Late Z-shaped drag folds and conjugate sets of kink bands overprint the cleavage.

Pontiac Domain

The Pontiac domain is located south of the Larder Lake–Cadillac deformation zone in the Pontiac Subprovince. It consists mainly of graded wacke and mudstone, with minor conglomerate, and mafic and ultramafic volcanic rocks (Gunning and Ambrose, 1940; Goulet, 1978). Early, locally preserved isoclinal folds are overprinted by the main regional cleavage (Perrouty et al., 2017), which strikes northwest and dips subvertically. The main cleavage is axial planar to regional upright and tight S-shaped folds, which define the map pattern in the Pontiac domain. The main cleavage contains a steep biotite lineation plunging to the east and is overprinted by late Z-shaped drag folds and kink bands.

SUMMARY

Conclusions of the report are summarized below:

- Conglomeratic units are present at the contact between volcanic terranes and sedimentary basins (e.g., Piché–Cadillac contact, Chicobi–Desboues contact). These units contain clasts of underlying volcanic rocks and represent erosional unconformities.

- Other conglomeratic units young toward older underlying volcanic rocks (e.g., Lac Caste–Malartic contact) and are in fault contact with the volcanic rocks.

- Domains along this transect have a strong, west-northwest–striking subvertical cleavage, which is axial planar to regional, isoclinal to tight, upright folds. A stretching lineation lies on the cleavage plane and typically plunges steeply near the contact between metavolcanic terranes and sedimentary basins. Late Z-shaped folds and kink bands overprint the cleavage.

These new mapping results will contribute to an improved understanding of the geological evolution that has taken place along the volcano-sedimentary domain boundaries. The faults along the boundaries of the Porcupine- and Timiskaming-style basins (e.g., Larder Lake–Cadillac Break, Porcupine–Destor–Manneville fault zones) are considered to be transcrustal structures based upon the presence of Archean lode-gold deposits along the structures as well as the successful tracing of similar structures in the Yilgarn craton (Goleby et al., 2004). These major transcrustal structures may well be displayed once seismic profiles are interpreted in the coming months. Integration of seismic and magnetotelluric data has allowed recognition of hydrothermal pathways in the Gawler craton (Heinson et al., 2018). It is hoped that the seismic and magnetotelluric data collected as part of the Metal Earth project will assist in identifying midcrustal structures, thus potentially distinguishing well-endowed terranes, such as the Abitibi, from less-endowed terranes, which is the fundamental goal of the Metal Earth initiative.

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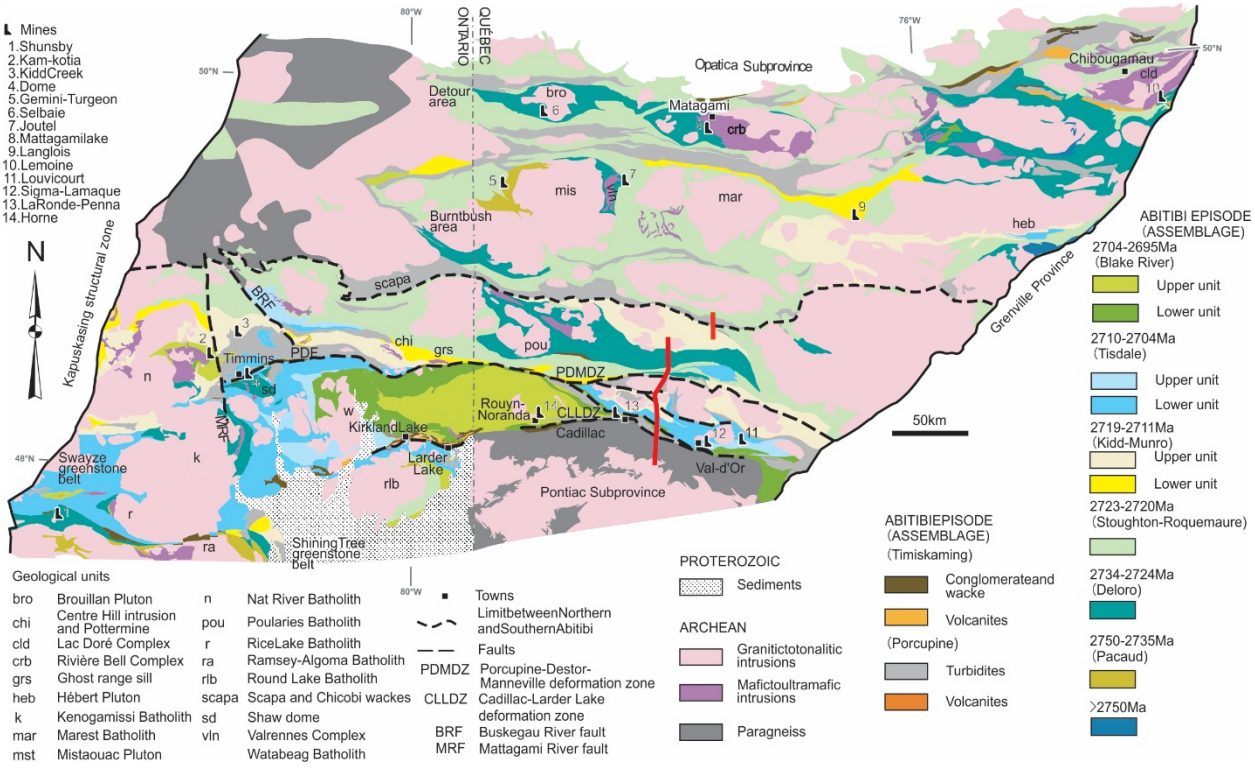

Figure 1 Tectonic framework of the southern Abitibi and Pontiac subprovinces. Figure modified from Thurston et al. (2008). The geology of the southern Abitibi greenstone belt is based on Ayer et al. (2005) and the Québec portion on Goutier and Melançon (2007). The location of the Malartic transect is indicated by a red solid line.

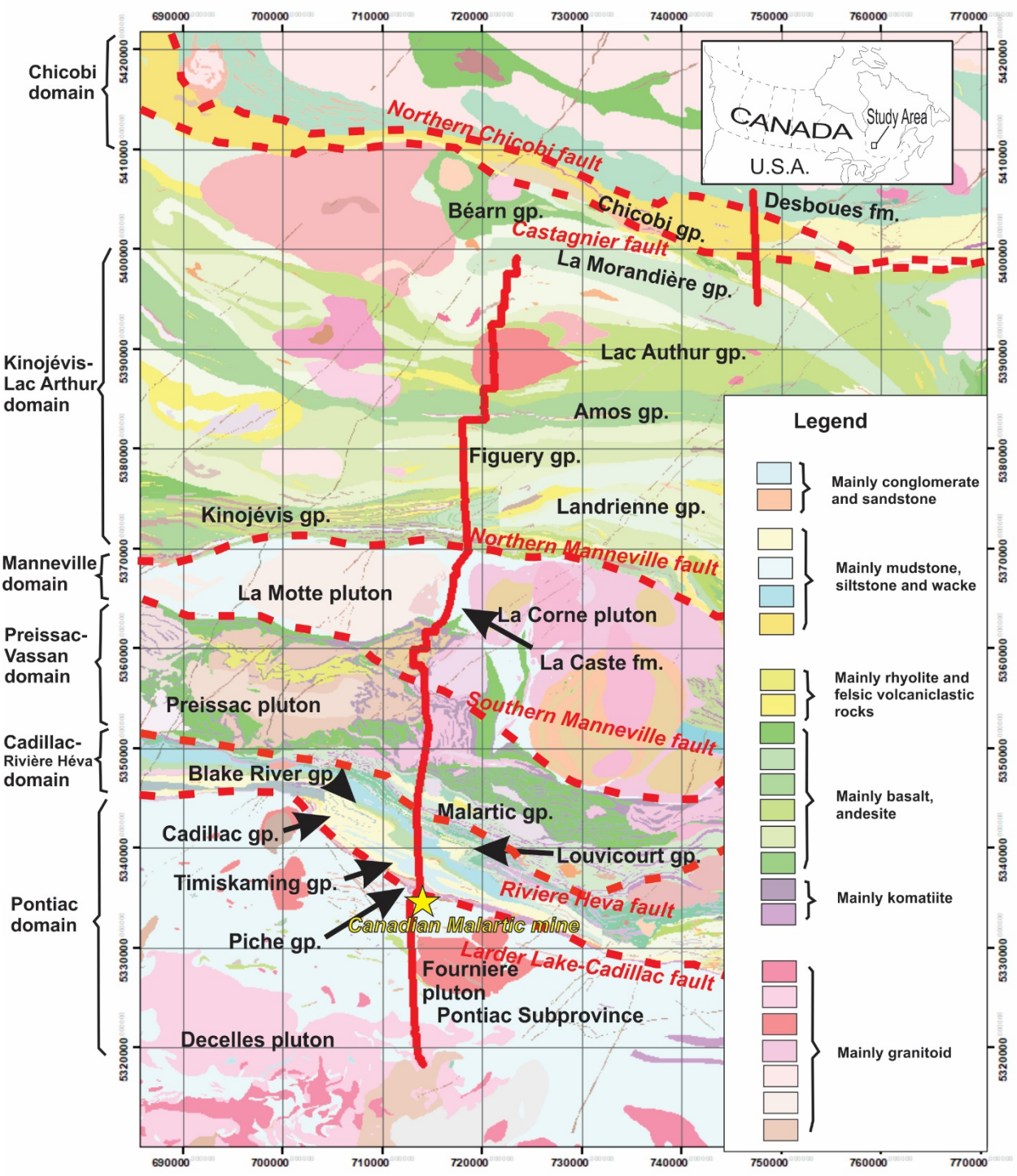

Figure 2 Regional geology of the Malartic transect area, southern Abitibi and Pontiac subprovinces. Figure *modified from* SIGEOM (2017). Major tectonostratigraphic domains are listed. The yellow star indicates the location of the Canadian Malartic mine. Abbreviations: Fm., formation; Gp., group.

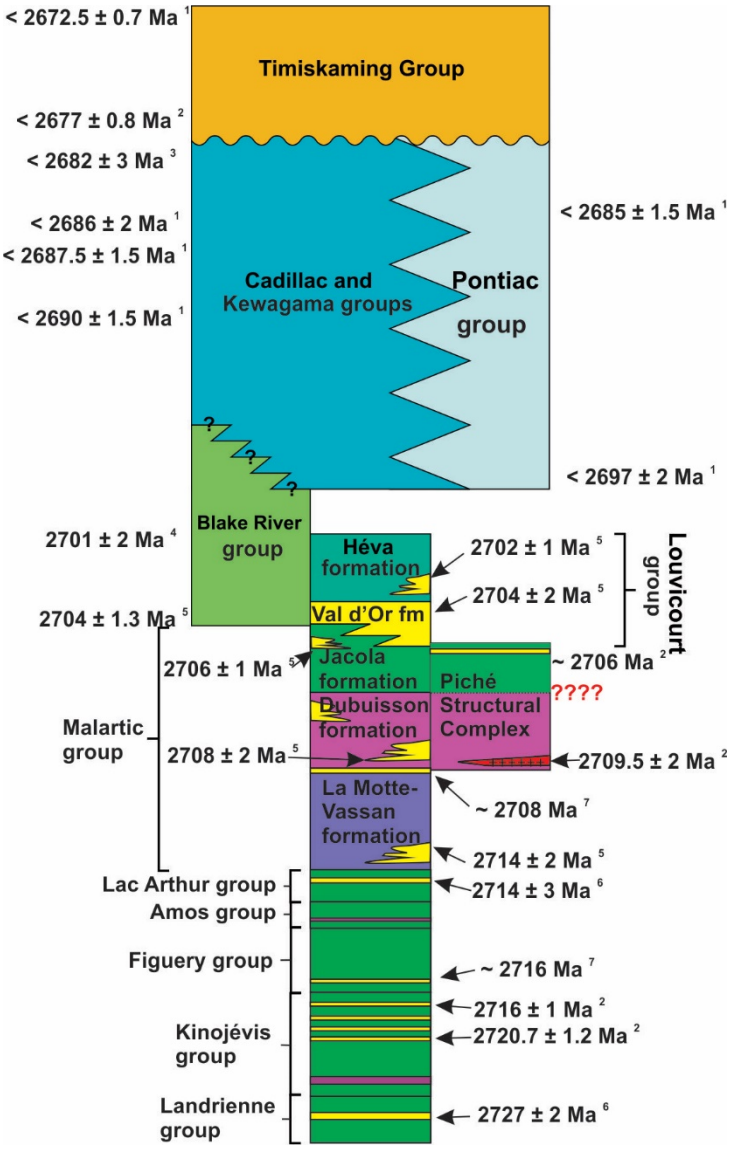

Figure 3 Lithostratigraphic column and related U-Pb geochronology data of the Malartic transect area, southern Abitibi and Pontiac subprovinces. Figure *modified from* Pilote et al. (2015) and Bedeaux et al. (2017). Source: [1]Davis (2002), [2]Pilote et al. (2015), [3]Mortensen (1993), [4]Corfu et al. (1989), [5]Pilote et al. (1999), [6]Labbé, 1999; [7]M. Hamilton (pers. comm., 2018).

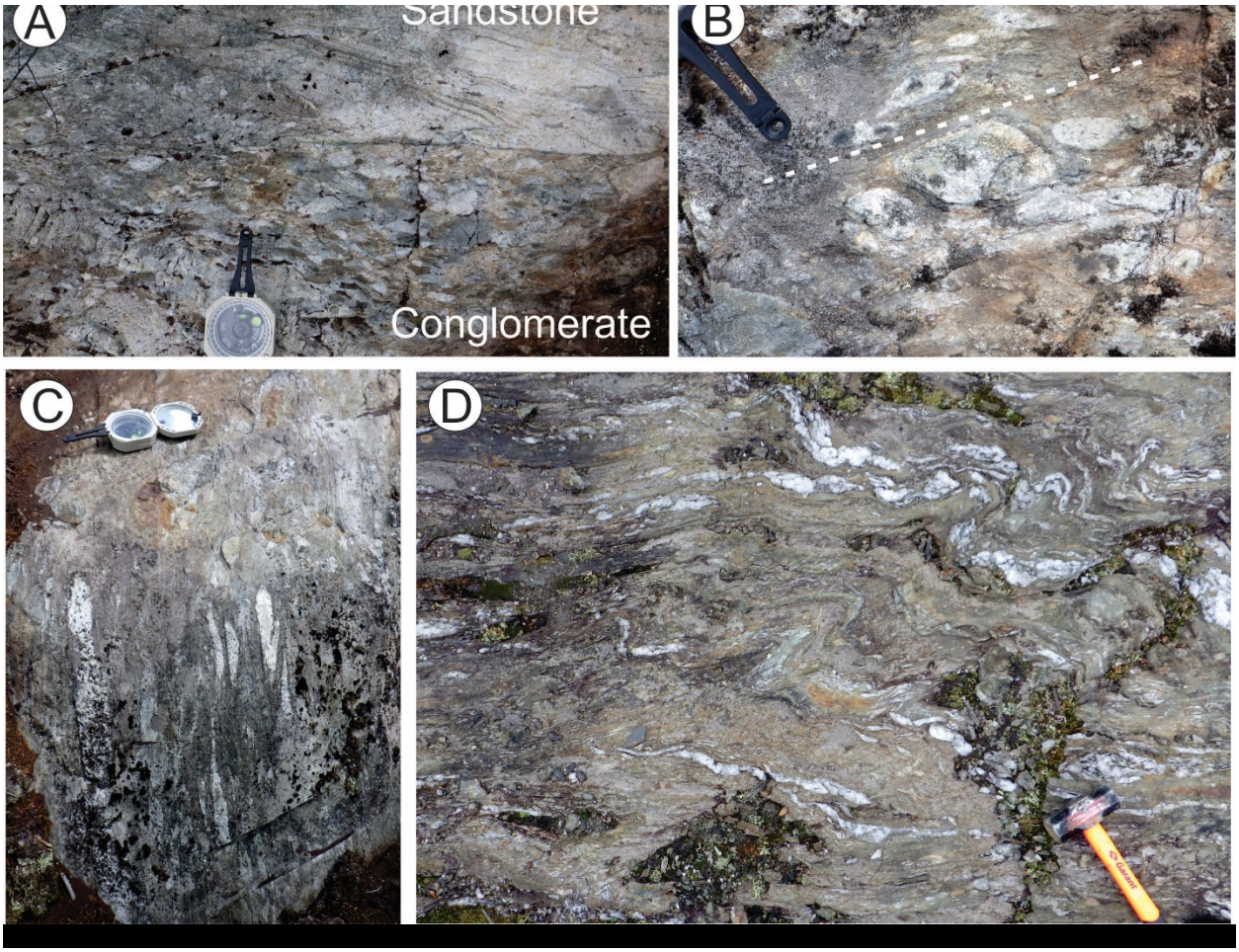

Figure 4 Outcrop photographs of the Chicobi domain, southern Abitibi and Pontiac subprovinces, showing: **a)** polymictic conglomerate unconformably overlying crossbedded sandstone; **b)** sinistral shearing along the main cleavage; **c)** steep stretching lineation defined by elongated granitoid clasts; **d)** main cleavage overprinted by late Z folds. Compass (22 cm in length) and hammer (25 cm in length) point to the north.

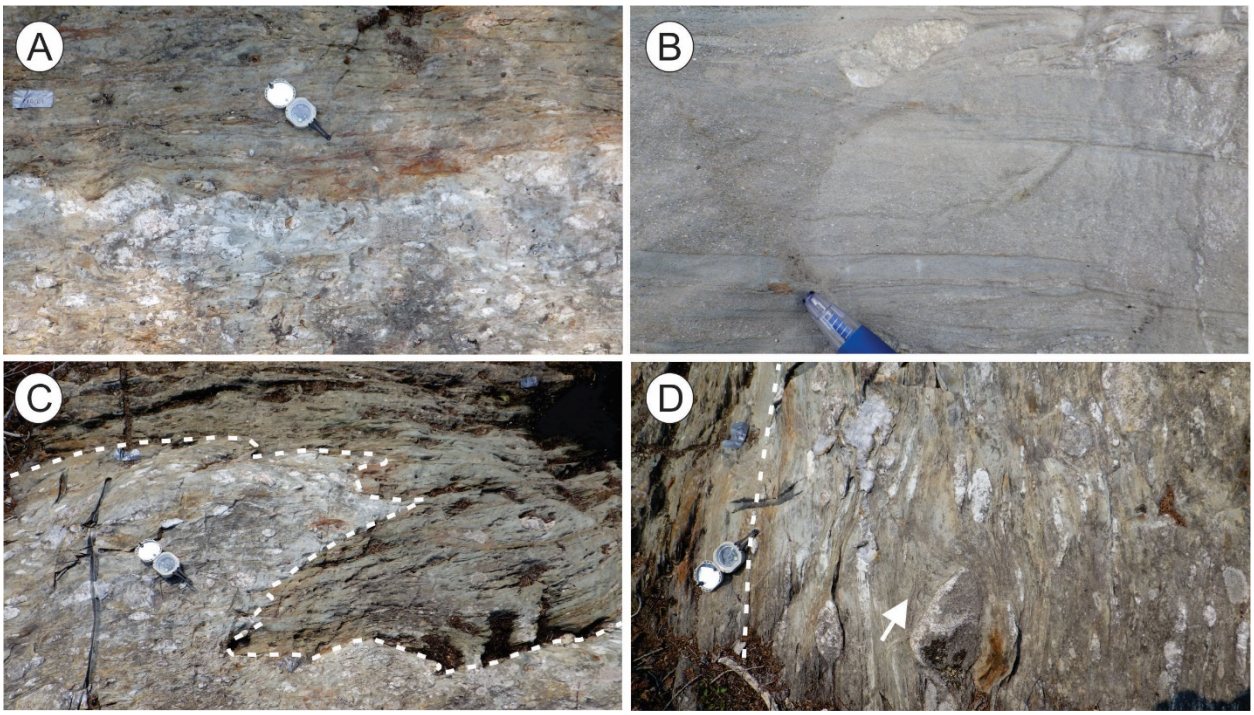

Figure 5 Field photographs of features near the contact between the Piché and Cadillac groups, southern Abitibi and Pontiac subprovinces, showing: **a)** a sharp contact between Piché group mafic flow and conglomerate of the Cadillac group basin; **b)** graded beds north of the contact younging to the northeast, away from the underlying metavolcanic rocks; **c)** overprinting of the contact by tight upright folds that are parasitic to regional folds (the contact is indicated by a white dashed line); **d)** asymmetrical strain shadows around the granitoid clasts, as indicated by an arrow (the contact is indicated by a white dashed line). Compass (22 cm in length) and pen (2 cm in length) point to the north.