ISSN 1916-6117 (online)
ISBN 978-1-4868-7220-6 (PDF)

ISSN 0826-9580 (print)
ISBN 978-1-4868-7219-0 (print)

It is recommended that reference to the Content be made in the following form:

Perrouty, S., Sherlock, R.L. and Simmons, J.M. 2023. Discovering the Abitibi gold belt: A geological guidebook; Geological Association of Canada–Mineralogical Association of Canada–Society for Geology Applied to Mineral Deposits, Joint Annual Meeting, Sudbury, Ontario, May 25–27, 2023, Field Trip FT02, Ontario Geological Survey, Open File Report 6392, 42p.

Ontario

Ontario Geological Survey
Open File Report 6392

Discovering the Abitibi Gold Belt: A Geological Guidebook

2023

Ontario

ONTARIO GEOLOGICAL SURVEY

Open File Report 6392

Discovering the Abitibi Gold Belt: A Geological Guidebook

by

S. Perrouty, R.L. Sherlock and J.M. Simmons

2023

Parts of this publication may be quoted if credit is given. It is recommended that reference to this publication be made in the following form:

Perrouty, S., Sherlock, R.L. and Simmons, J.M. 2023. Discovering the Abitibi gold belt: A geological guidebook; Geological Association of Canada–Mineralogical Association of Canada–Society for Geology Applied to Mineral Deposits, Joint Annual Meeting, Sudbury, Ontario, May 25–27, 2023, Field Trip FT02, Ontario Geological Survey, Open File Report 6392, 42p.

Users of OGS products should be aware that Indigenous communities may have Aboriginal or treaty rights or other interests that overlap with areas of mineral potential and exploration.

ISBN 978-1-4868-7219-0 (print)
ISBN 978-1-4868-7220-6 (PDF)

Open File Reports of the Ontario Geological Survey are available for viewing at the John B. Gammon Geoscience Library in Sudbury and at the regional Mines and Minerals office whose district includes the area covered by the report (see below).

Copies can be purchased at Publication Sales and the office whose district includes the area covered by the report. Although a particular report may not be in stock at locations other than the Publication Sales office in Sudbury, they can generally be obtained within 3 working days. All telephone, fax, mail and e-mail orders should be directed to the Publication Sales office in Sudbury. Purchases may be made using cash, debit card, VISA, MasterCard, cheque or money order. Cheques or money orders should be made payable to the *Minister of Finance*.

John B. Gammon Geoscience Library 933 Ramsey Lake Road, Level B2 Sudbury, Ontario P3E 6B5	Tel:	(705) 670-5614
Publication Sales 933 Ramsey Lake Rd., Level B2 Sudbury, Ontario P3E 6B5	Tel: Toll-free: Fax: E-mail:	(705) 670-5691 (local) 1-888-415-9845 ext. 5691 (705) 670-5770 pubsales.ndm@ontario.ca

Regional Mines and Minerals Offices:

Kenora – Suite 104, 810 Robertson St., Kenora P9N 4J2

Kirkland Lake – 1451 Hwy. 66, P.O. Box 40, Swastika P0K 1T0

Red Lake – 227 Howey Street, P.O. Box 324, Red Lake P0V 2M0

Sault Ste. Marie – 740 Great Northern Rd., Sault Ste. Marie P6A 5M1

Southern Ontario – 126 Old Troy Rd., Tweed K0K 3J0

Sudbury – 933 Ramsey Lake Rd., Level B2, Sudbury P3E 6B5

Thunder Bay – Suite B002, 435 James St. S., Thunder Bay P7E 6S7

Timmins – Ontario Government Complex, P.O. Bag 3060, 5520 Hwy. 101 East, South Porcupine P0N 1H0

Cette publication est disponible en anglais seulement.

Parts of this report may be quoted if credit is given. It is recommended that reference be made in the following form:

Perrouty, S., Sherlock, R.L. and Simmons, J.M. 2023. Discovering the Abitibi gold belt: A geological guidebook; Geological Association of Canada–Mineralogical Association of Canada–Society for Geology Applied to Mineral Deposits, Joint Annual Meeting, Sudbury, Ontario, May 25–27, 2023, Field Trip FT02, Ontario Geological Survey, Open File Report 6392, 42p.

Contents

FIGURES

PHOTOS

Preface

This geological field trip guidebook was prepared initially for use with a field trip (trip number FT06) for the joint annual meeting of the Geological Association of Canada, the Mineralogical Association of Canada and the Society for Geology Applied to Mineral Deposits (GAC–MAC–SGA) held in Sudbury, Ontario, May 25–27, 2023.

Sudbury is one of the world's premier nickel-copper mining districts, a significant platinum group element (PGE) producer, and one of the oldest, largest, and best-exposed meteorite impact sites on Earth. As the world's largest integrated mining technology cluster, Sudbury has a vibrant mineral exploration and mining community that includes several major producers, numerous junior exploration companies, dozens of mining supply and service companies, 3 post-secondary educational institutions and associated exploration and mining centres, and several Ontario government mining and mineral ministry offices, making Sudbury one of the best places in the world to host a multidisciplinary meeting of this type. The City of Greater Sudbury, the largest city by landmass in Ontario, lies amidst glacially shaped ridges, green boreal forests, and contains 330 lakes over 10 hectares in size and 112 lakes over 100 hectares in size. The success of more than 40 continuous years of environmental reclamation efforts has led to numerous national and international awards, including a Government of Canada *Environmental Achievement Award*, a United States *Chevron Conservation Award*, and a United Nations *Local Government Honours Award*. And, as part of Sudbury's continuing regreening efforts, the milestone 10 millionth tree was planted in July 2022.

The theme of the GAC–MAC–SGA meeting—"Discovering Ancient to Modern Earth"—reflects the location of the meeting at the intersection of the Archean Superior Province and Proterozoic Southern and Grenville provinces, and Paleozoic–Quaternary cover sequences. The hybrid conference included a technical program of oral and poster presentations in Symposia, Special Sessions and Regular Sessions covering the complete spectrum of geoscience disciplines, which were complemented by 10 field trips, 6 workshops and 1 short course.

The meeting was hosted by the Harquail School of Earth Sciences and the Mineral Exploration Research Centre (MERC) at Laurentian University.

Abstract

With over 300 million ounces (Moz) of gold produced, the Abitibi is the world's best endowed Precambrian greenstone belt. This 4-day field trip introduces the regional lithostratigraphy, major deformation zones and key mineral deposits present in the Abitibi greenstone belt between Timmins (Ontario) and Val d'Or (Québec). The originally proposed program had included mine tours and drill core viewing at the metakomatiite-hosted Kerr-Addison gold camp (~11 Moz) near Larder Lake, the metabasalt-hosted Sigma–Lamaque gold camp (15 Moz) near Val d'Or and the metasediment-hosted Canadian Malartic gold camp (~26 Moz). Stops for Day 1 are in Timmins, for Day 2 in Kirkland Lake, for Day 3 in Larder Lake and Rouyn-Noranda, and for Day 4 in Val d'Or and Malartic.

Discovering the Abitibi Gold Belt: A Geological Guidebook

S. Perrouty[1], R.L. Sherlock[2] and J.M. Simmons[3]

Ontario Geological Survey
Open File Report 6392
2023

---

[1]Associate Professor, Mineral Exploration Research Centre, Harquail School of Earth Sciences, Laurentian University, 935 Ramsey Lake Road, Sudbury, Ontario P3E 2C6; sperrouty@laurentian.ca
[2]Professor, Mineral Exploration Research Centre, Harquail School of Earth Sciences, Laurentian University, 935 Ramsey Lake Road, Sudbury, Ontario P3E 2C6; rsherlock@laurentian.ca
[3]Post-Doctoral Fellow, Mineral Exploration Research Centre, Harquail School of Earth Sciences, Laurentian University, 935 Ramsey Lake Road, Sudbury, Ontario P3E 2C6; jsimmons@laurentian.ca

Introduction

The southern Abitibi is the world's best endowed Precambrian greenstone belt in terms of base (copper-zinc) and precious (gold-silver) metals. Past production and current resources include >300 million ounces (Moz) of orogenic gold, >40 Moz of volcanogenic gold (Dubé and Mercier-Langevin 2020), and >775 million tonnes (Mt) of volcanogenic massive sulfide (VMS) mineralization (Monecke, Gibson and Goutier 2017) (Figure 1).

Since the first discovery of gold in 1906 in Timmins and Porcupine, and copper in 1922 in Noranda, the Abitibi greenstone belt has been the focus of extensive mining activities and academic research. Comprehensive reviews of Abitibi geology and associated mineral deposits are available in the Society of Economic Geologists 2017 book *Archean Base and Precious Metal Deposits, Southern Abitibi Greenstone Belt, Canada* (Reviews in Economic Geology v.19, edited by T. Monecke, P. Mercier-Langevin and B. Dubé). Abitibi gold systems are further documented by Dubé and Mercier-Langevin (2020, and references therein).

This field trip introduces the overall supracrustal stratigraphy, magmatic evolution and structural controls of the main mining camps, including from west to east:

- Timmins (~84 Moz of gold)
- Kirkland Lake (~31 Moz of gold)
- Larder Lake (~13 Moz of gold)
- Noranda (~357 Mt VMS mineralization)
- Malartic (~27 Moz of gold)
- Val d'Or (~29 Moz of gold).

Safety

For users of this guidebook, please bear in mind that some of the stops listed in this guidebook involve travel along gravel roads, as well as semi-isolated work in the bush. Therefore, standard bush safety practices should be followed by users of this guidebook. Such practices include travelling in pairs; advising others of your starting time and location and your expected return time; carrying sufficient water for the trip; being prepared for sudden changes in the weather; and carrying the appropriate emergency and safety gear. Participants should bring hiking boots, a toque, gloves, rain jacket, pants, sweater, short- and long-sleeve shirts, hat, sunscreen, any medication(s) needed, notebook, pencils and hand lens; and hard hats, safety vests and safety glasses if they bring a hammer. Care should always be exercised when parking, exiting vehicles and crossing the roads. Use of safety vests and/or bright clothing is recommended to improve your visibility to motorists. Site-specific hazard information is provided at the beginning of each individual field trip stop, as needed. Many of the stops are at sites on land controlled by companies, so permission is required.

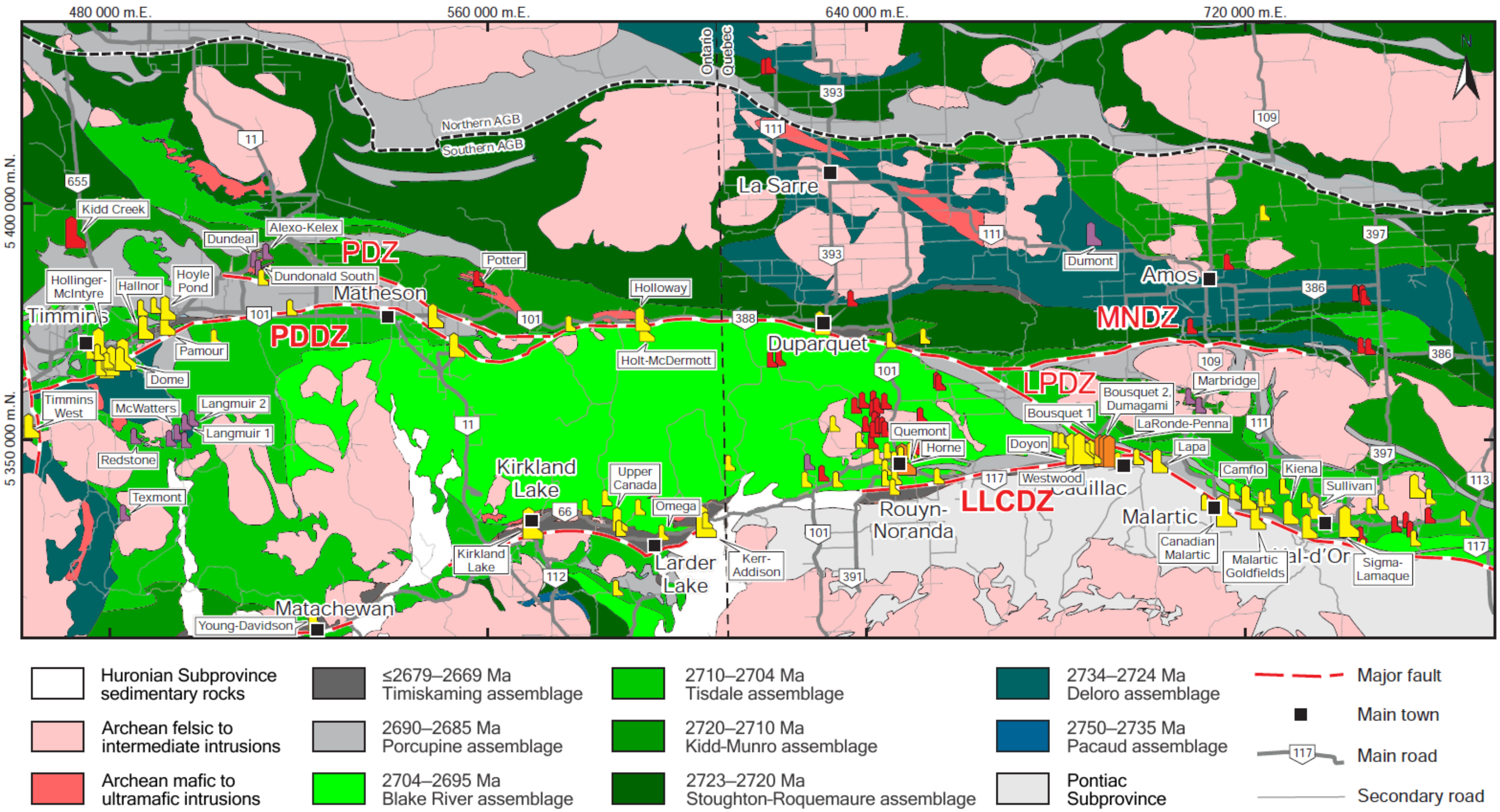

Figure 1. Geological map of the Abitibi greenstone belt (AGB) (*modified from* Monecke, Gibson and Goutier 2017). Key deposits are shown using colour-filled headframe symbols: gold deposits in yellow, gold-rich volcanogenic massive sulphide (VMS) deposits in orange, base metal VMS deposits in red, and nickel-copper-PGE deposits in purple. Abbreviations: LLCDZ, Larder Lake–Cadillac deformation zone; LPDZ, La Pause deformation zone; MNDZ, Manneville North deformation zone; PDZ, Pipestone deformation zone; PDDZ, Porcupine–Destor deformation zone.

Road Logs

Note: Caution should be taken when parking vehicles on the shoulders of the road or highways and when examining outcrops located along the field trip route. All Universal Transverse Mercator (UTM) co-ordinates are provided using North American Datum 1983 (NAD83) in Zone 17N. Note that stops for Day 4 are in Zone 18, with co-ordinates provided in both zones 17N and 18N.

As indicated in Figure 2, the trip is designed as 4 day-long segments, with the trip starting in the City of Greater Sudbury and ending in Val d'Or or Greater Sudbury. Note that the first stop of Day 1 is located adjacent to Highway 144 south of Timmins.

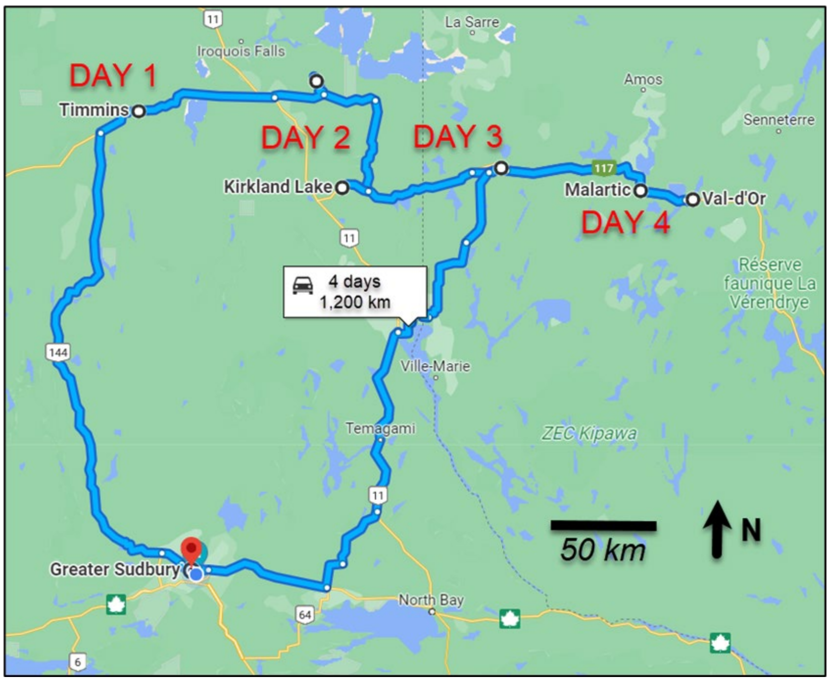

Figure 2. Map showing the 4 suggested day-long segments of the field trip. Routing is based on the trip starting and ending in the City of Greater Sudbury. Image *from* Google Maps™ mapping service, image © 2023 Google LLC.

DAY 1. TIMMINS MINING CAMP

Stop 1-1: Kenogamissi Batholith (445860E 5282470N)
Stop 1-2: Timiskaming metaconglomerate "sample" (475880E 5369020N)
Stop 1-3: Variolitic pillow basalts, Tisdale assemblage (478180E 5368950N)
Stop 1-4: Altered amygdaloidal pillow basalts, Tisdale assemblage (476080E 5368880N)
Stop 1-5: Hollinger pit lookout (476180E 5368770N) (requires permission to visit)
Stop 1-6: Ankerite alteration, Tisdale assemblage (487220E 5370720N)
Stop 1-7: Porcupine assemblage–Timiskaming assemblage unconformity (484380E 5371480N)
Day ends in Timmins

The Watershed on Highway 144.

The gas station and shop are located approximately midway between Sudbury and Timmins (UTM 436220E 5257920N). It is a popular stop for travellers. The watershed divides the Atlantic (i.e., Great Lakes) and Arctic (i.e., Hudson Bay) water flows.

At the junction of Highways 144 and 661, turn right and follow Highway 661 toward the community of Gogama. Stop 1-1 is located on Highway 661, approximately 1.2 km south of the junction with Highway 144.

Stop 1-1. Kenogamissi Batholith

UTM 445860E 5282470N

Potential hazards:

- Steep and/or slippery slopes; loose rocks
- Busy road with high-speed traffic; stay off road shoulder and remain away from parked vehicles if possible; high-visibility vests required

The Kenogamissi Batholith is one of best studied intrusive complexes in the Superior Province (Figures 3A and 3B). The aim of the stop is to highlight the protracted magmatic history and compositional variations of the Kenogamissi Batholith, to contrast with the typical "pink blobs" that are drawn on most geological maps.

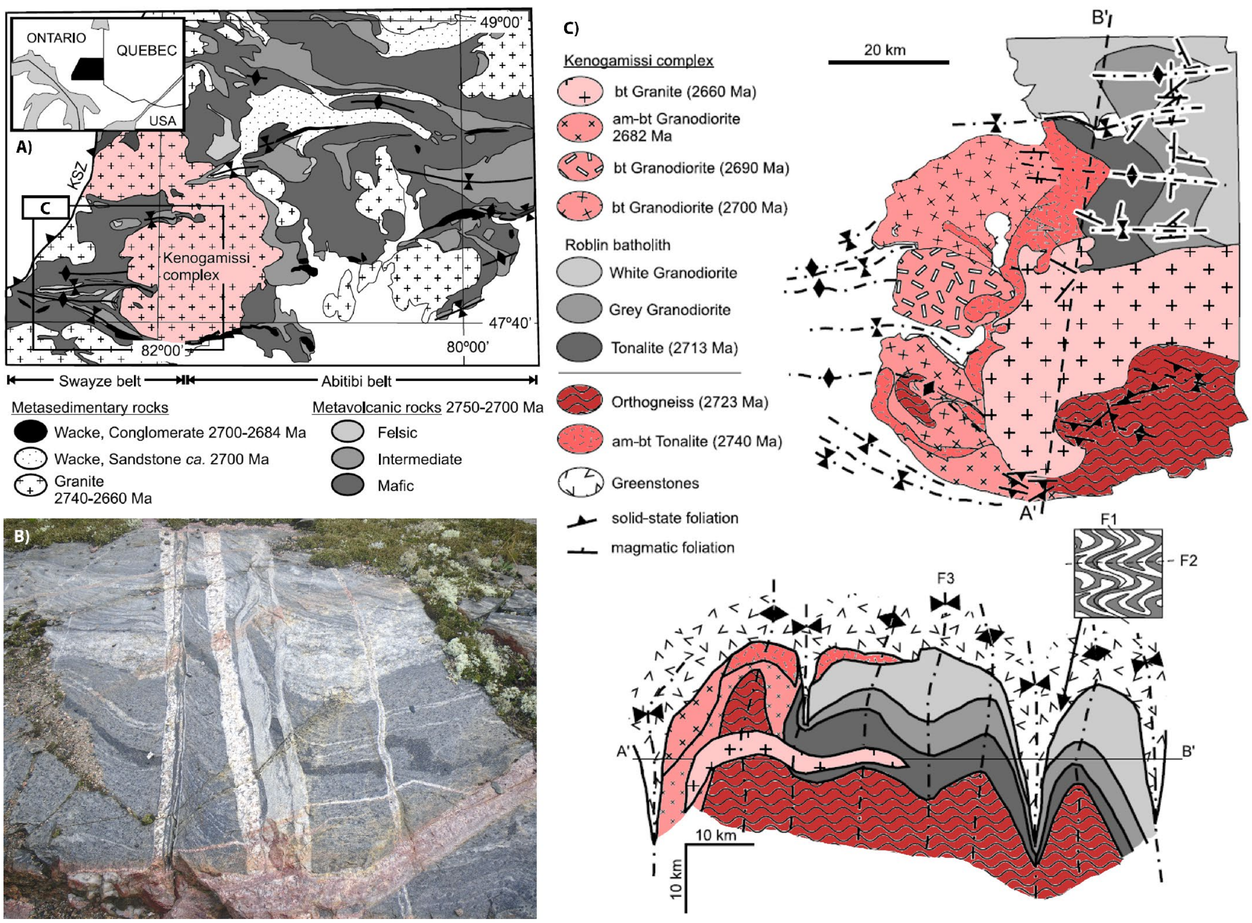

Figure 3. **A)** Location of the Kenogamissi Batholith (*modified from* Benn 2004). **B)** Field photograph (the outcrop shown in the image is ~1 m wide). **C)** Geological map and cross section (*modified from* Benn 2004). Abbreviations: am, amphibole; bt, biotite.

Magmatism in the Kenogamissi Batholith spans approximately 80 million years (Benn 2004) (Figure 3C). It began with synvolcanic tonalite-trondhjemite-granodiorite (TTG) intrusions (now Gogama gneisses) at *circa* 2740–2720 Ma, which are similar in age and composition to the intrusions spatially associated with gold at the nearby Côté Gold deposit (Katz et al. 2017). Subsequently, a series of crosscutting tonalite to granodiorite sills and dikes formed in the southern Abitibi during the main phase of volcanism at *circa* 2720–2690 Ma and were followed by late syn-orogenic granodiorite to granite sills and dikes intruded at *circa* 2680–2660 Ma (Benn 2004).

Following the stop, retrace the route back to Highway 144, turn right, and continue on Highway 144 northward to Timmins.

Table 1. Summary of southern Abitibi greenstone belt supracrustal assemblage names, ages, basal contacts, rock types and chemical affinities. These terms are used for stops on Days 1, 2 and 3. Table *modified from* Ayer et al. 2005).

Assemblage Name (Age in Ma)	Includes Previously Identified Formations and Groups	Basal Contact Relationships	Dominant Rock Types
Timiskaming (≤2679–2669)	Timiskaming, Dome, Three Nations, Hearst	Angular unconformity	Conglomerate, sandstone, mafic to intermediate volcanic
Porcupine (2690–2685)	Porcupine, Krist, Beatty, Hoyle, Whitney, Hearst	Angular unconformity	Turbidite, minor conglomerate and iron formation
Blake River (2704–2695)	Blake River, Kamiskotia, Skead, Kinojevis, Garrison	Conformable	Mafic to felsic volcanic
Tisdale (2710–2704)	Tisdale, Marker Horizon, Duff, Coulson, Gauthier, Bowman, Larder Lake	Conformable to unconformable	Ultramafic, mafic, intermediate to felsic volcanic and iron formation
Kidd–Munro (2720–2710)	Munro, Coulson, Rand	Conformable to unconformable	Ultramafic, mafic, intermediate to felsic volcanic and iron formation
Stoughton– Roquemaure (2723–2720)	Stoughton–Roquemaure, Kinojevis, Wabewawa, Catherine	Conformable to unconformable	Ultramafic, mafic, intermediate and felsic volcanic
Deloro (2730–2724)	Upper Deloro, Redstone River	Unconformable	Mafic, intermediate and felsic volcanic and iron formation
Pacaud (2750–2735)	Pacaud, lower Deloro	Unknown – removed by intrusions	Ultramafic, mafic and felsic volcanic

Stop 1-2. Timiskaming metaconglomerate "sample"

UTM 475880E 5369020N

Potential hazards:

- Business area, watch for local traffic

This gold mineralized (3.5 g/t Au) sample of Timiskaming metaconglomerate is located next to the Timmins Public Library and nearby the Timmins Museum. It includes clasts of mafic to felsic igneous rocks, clastic and chemical sedimentary rocks, and rare quartz fragments (Figure 4A). It is an excellent introduction to the polymictic metaconglomerate that are characteristic of the Timiskaming assemblage (2679–2669 Ma; Frieman et al. 2017) (Table 1) (Figure 4B). The presence of Timiskaming-like molasse (i.e., terrestrial or shallow marine deposits that form in front of a rising mountain chain) in the Abitibi greenstone belt (and other Precambrian greenstone belts) is a geological marker of a nearby major deformation zone, such as the Porcupine–Destor deformation zone (PDDZ) and the Larder Lake–Cadillac deformation zone (LLCDZ), which may host orogenic gold resources (Figure 4C).

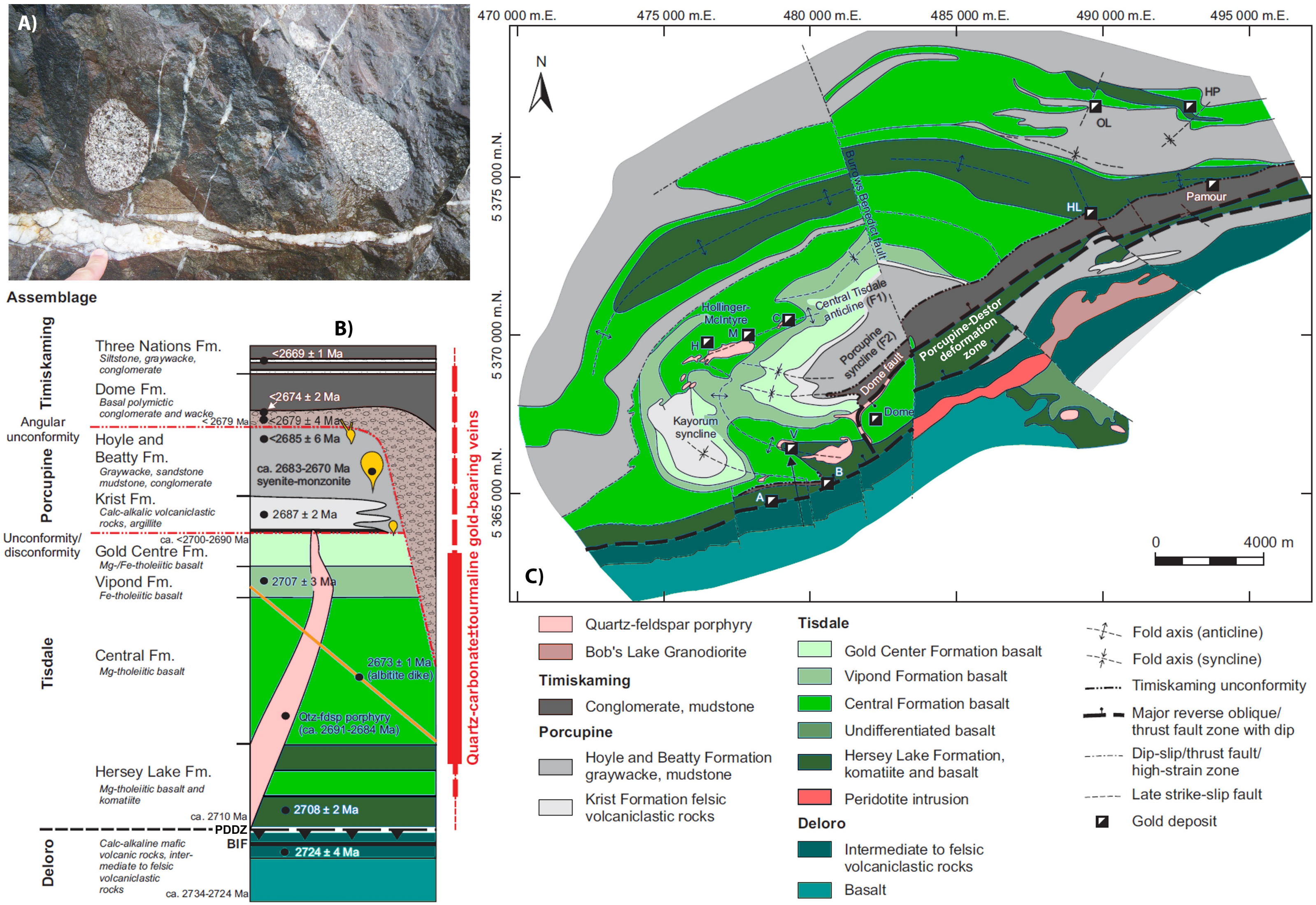

Figure 4. A) Field photograph (the outcrop shown in the image is ~0.5 m wide), showing the Temiskaming metaconglomerate at Stop 1-2. **B)** Stratigraphy of the Timmins mining camp (*modified from* Dubé et al. 2020, *modified from* Bleeker and van Breemen 2011). Abbreviations: BIF, banded iron formation; Fm, formation; PDDZ, Porcupine–Destor deformation zone; Qtz-fdsp, quartz-feldspar. **C)** Geological map of the Timmins mining camp (*modified from* Dubé et al. 2020). Mine abbreviations: A, Aunor Delnite; B, Buffalo Ankerite; C, Coniaurum; H, Hollinger; HL, Halnor; HP, Hoyle Pond; M, McIntyre; OL, Owl Creek; V, Vedron.

Stop 1-3. Variolitic pillow basalts, Tisdale assemblage

UTM 478180E 5368950N

Potential hazards:

- Steep and/or slippery slopes; loose rocks; garbage
- In town, watch for local traffic

The Tisdale assemblage (2710–2704 Ma; Frieman et al. 2017) is the main host of orogenic gold mineralization in the Timmins mining camp. It primarily includes ultramafic to mafic metavolcanic rocks that locally display supercooled rock textures (Fowler et al. 2002). The stop is located south of Templeton Avenue in the Schumacher neighborhood, east of the Hollinger pit.

The outcrop is the best example of a variolitic pillowed flow in the Timmins mining camp (Photo 1). Varioles at this location correspond to plagioclase spherules crystallized from a supercooled mafic magma. The presence of variolitic flows can be used as stratigraphy horizons within a volcanic sequence. Additionally, the shape of the varioles after deformation (e.g., pancakes versus cigars) is a great structural marker in metavolcanic rocks. Here, the elongation of the varioles defines an east-plunging stretching lineation. Fowler et al. (2002) provides a detailed description of the different type of varioles and their origin in the Abitibi greenstone belt.

Photo 1. Field photograph of the variolitic pillowed flow at Stop 1-3 (the outcrop shown in the image is ~1 m wide).

Stop 1-4. Altered amygdaloidal pillow basalts, Tisdale assemblage

UTM 476080E 5368880N

Potential hazards:

- Steep and/or slippery slopes; loose rocks
- In town, watch for local traffic
- Outcrops are near a mine access road with truck traffic; stay off road shoulder and remain away from parked vehicles if possible; high-visibility vests required

The outcrop, south of Brunette Road and west of the Hollinger pit, displays amygdaloidal pillow basalts of the Tisdale assemblage (Photo 2). The pillow shape is extremely stretched on the vertical face of the outcrop, but is well preserved on the horizontal face. Quartz-carbonate-sericite-pyrite alteration is also pervasive on the vertical face, but is difficult to document on the horizontal face. The stop outlines the importance of investigating outcrops in 3 dimensions during regional mapping and/or mineral exploration.

Amygdules correspond to gas bubbles generated during the emplacement of volcanic flows. This primary porosity is commonly filled by carbonate mineral and/or quartz during seafloor alteration, burial, or metamorphism, and can account for a significant part of the CO_2 budget present in Precambrian greenstone belts. Similar to the varioles, the amygdules can be used as a deformation marker in metavolcanic rocks. Here, they outline a subvertical stretching lineation.

Photo 2. Photograph of amygdaloidal pillow basalts at Stop 1-4 (the outcrop shown in the image is ~0.8 m wide).

Stop 1-5. Hollinger pit lookout

UTM 476180E 5368770N

Potential hazards:

- In town, watch for local traffic
- Open to public during the summer from June 1 to September 30.
  Access in the winter requires permission from Newmont Corporation Porcupine operations.

The Hollinger gold deposit (~19.8 Moz of gold), discovered in 1909, was mined underground until the late 1960s at an average grade around 9.94 g/t Au. Open pit operations began in the 2010s at an average grade around 1 g/t Au (Figure 5A). The main host rocks correspond to mafic metavolcanic flows of the Tisdale assemblage and quartz-feldspar porphyry dikes (2691–2684 Ma; Dubé et al. 2020) (Figure 5B).

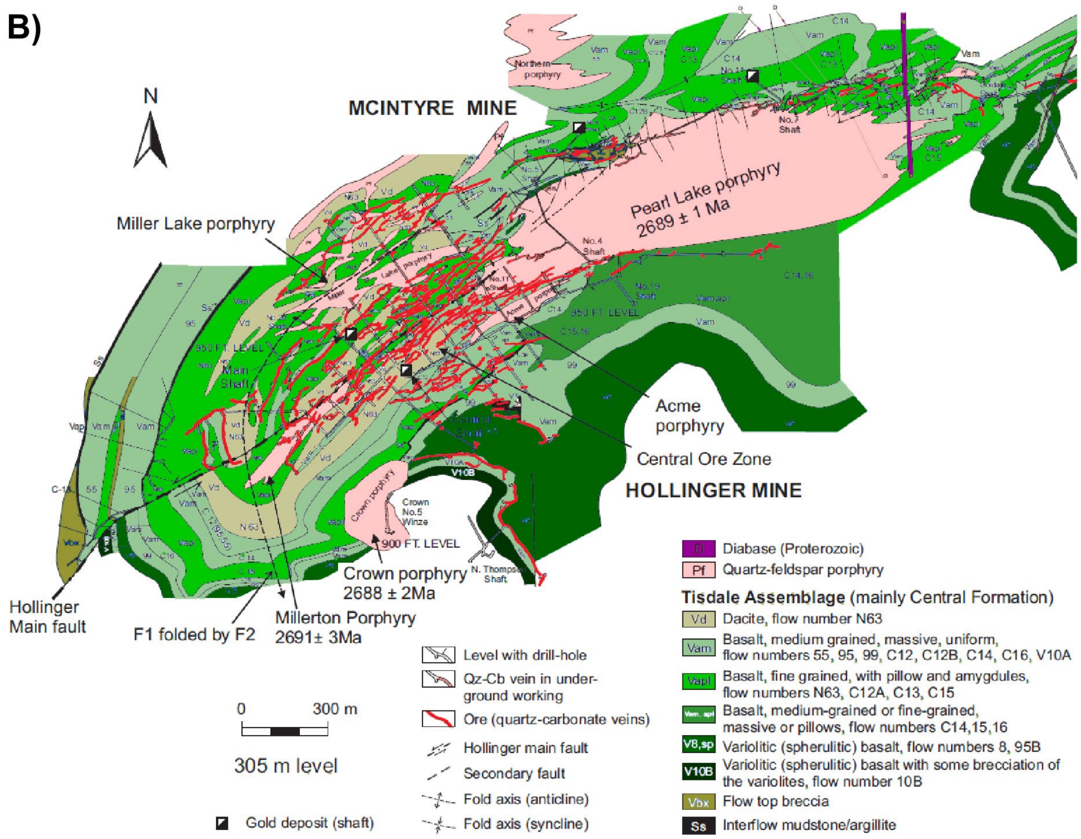

Figure 5. A) Panoramic view of the Hollinger pit viewed from Stop 1-5. **B)** Geological map of the Hollinger Mine (*modified from* Dubé et al. 2020, *modified from* Ferguson et al. 1968). Abbreviations: Qz-Cb, quartz-carbonate; map units defined in legend.

Stop 1-6. Ankerite alteration, Tisdale assemblage

UTM 487220E 5370720N

Potential hazards:

- Steep and/or slippery slopes near water; loose rocks
- In town on a side street, park appropriately if possible; high-visibility vests required
- Requires a short walk through bush to the lake shore

The stop is located on the eastern shore of Porcupine Lake, about 5 km northeast of the Dome Mine (~16.6 Moz of gold), and about 5 km southwest of the Pamour Mines (~5.5 Moz of gold; Dubé et al. 2020). It is located within the Porcupine–Destor deformation zone and displays extensive quartz-carbonate alteration (mainly ankerite) of ultramafic–mafic metavolcanic flows of the Tisdale assemblage (Photo 3).

Photo 3. Field photograph of quartz-carbonate alteration and veins at Stop 1-6 (the outcrop shown in the image is ~2 m wide).

Stop 1-7. Porcupine–Timiskaming unconformity

UTM 484380E 5371480N

Potential hazards:

- Steep and/or slippery slopes; loose rocks
- Parking is on a busy road with truck traffic; stay off road shoulder and remain away from parked vehicles if possible; high-visibility vests required
- Requires a short walk on a trail

The angular unconformity between the Porcupine (2690–2685 Ma; Frieman et al. 2017) and Timiskaming (2679–2669 Ma; Frieman et al. 2017) assemblages is visible on several outcrops approximately 200 m west of Davidson Mine Road north of Porcupine (Photo 4).

The Porcupine Basin consists primarily of coarse- to fine-grained clastic metasedimentary rocks, and is bounded by the Porcupine–Destor deformation zone (PDDZ) to the south and the Pipestone deformation zone to the north. Proximal to the PDDZ, the Porcupine assemblage metaturbidites are uncomformably overlain by the metasedimentary rocks of the Timiskaming assemblage that were deposited as a molasse (i.e., terrestrial or shallow marine deposits that form in front of a rising mountain chain). A couple of barren quartz veins are also present in the outcrops.

Photo 4. Photograph of Timiskaming assemblage metasedimentary rocks (molasse) (bottom) unconformably deposited on folded and foliated Porcupine assemblage metaturbidites (top) at Stop 1-7. Scale card is 9 cm long. The outcrop shown in the image is approximately 0.5 m wide.

DAY 2. KIRKLAND LAKE MINING CAMP

Stop 2-1: Pyke's Hill, Kidd–Munro assemblage (559170E 5383270N) (requires permission to visit)
Stop 2-2: Volcanogenic massive sulphide in drill core, Potter Mine (558190E 5383280N) (requires permission to visit)
Stop 2-3: Diamictite, Huronian Supergroup (559610E 5327980N)
Stop 2-4: Metaconglomerates, Timiskaming assemblage (569660E 5332380N)
Stop 2-5: Discovery Outcrop (571990E 5333900N)
Stop 2-6: Alkalic metavolcaniclastic rocks, Timiskaming assemblage (571550E 5334350N)
Stop 2-7: Alkalic intrusive rocks, Timiskaming assemblage (570830E 5333040N)
Stop 2-8: Alkalic intrusive rocks, Timiskaming assemblage (570920E 5332710N)
Day ends in Kirkland Lake

Stop 2-1. Pyke's Hill, Kidd–Munro assemblage

UTM 559170E 5383270N

Caution: Access requires permission from Millstream Mines Limited and wearing of steel-toed boots, high-visibility vests, safety glasses and hard hats. The company may stipulate other conditions for access.

Pyke's Hill displays the most spectacular series of metakomatiite flows in the Abitibi greenstone belt (Photos 5A, 5B and 5C), part of the Kidd–Munro assemblage (2720–2710 Ma; Frieman et al. 2017). A detailed description of the outcrop is provided in Houlé, Lesher and Préfontaine (2017, and references therein). The stop is located on a trail, 7 km north of Highway 101, 24 km east of Matheson.

Photo 5. A) Photograph of spinifex-textured metakomatiites at Pyke's Hill (Stop 2-1) (the outcrop shown in the image is ~0.5 m wide). **B)** Columnar ultramafic–mafic metavolcanic rock (the outcrop shown in the image is ~1 m wide). **C)** Mafic metavolcaniclastic rock (the outcrop shown in the image is ~0.8 m wide).

Stop 2-2. Volcanogenic massive sulphide in drill core, Potter Mine

UTM 558190E 5383280N

Caution: Access requires permission from Millstream Mines Limited and wearing of steel-toed boots, high-visibility vests, safety glasses and hard hats. The company may stipulate other conditions for access.

The Potter Mine (Figure 6A), 1 km west of Pyke's Hill, is a copper-zinc volcanogenic massive sulfide (VMS) deposit spatially associated with metabasaltic and metakomatiitic flows of the Kidd–Munro assemblage (Figures 6C and 6B). It was mainly explored and mined in the late 1960s, although significant resources are still inferred to remain (~5 Mt, Berger 2011). The geological setting and alteration assemblages have been documented by Coad (1976), Préfontaine (2013) and Houlé, Lesher and Préfontaine (2017).

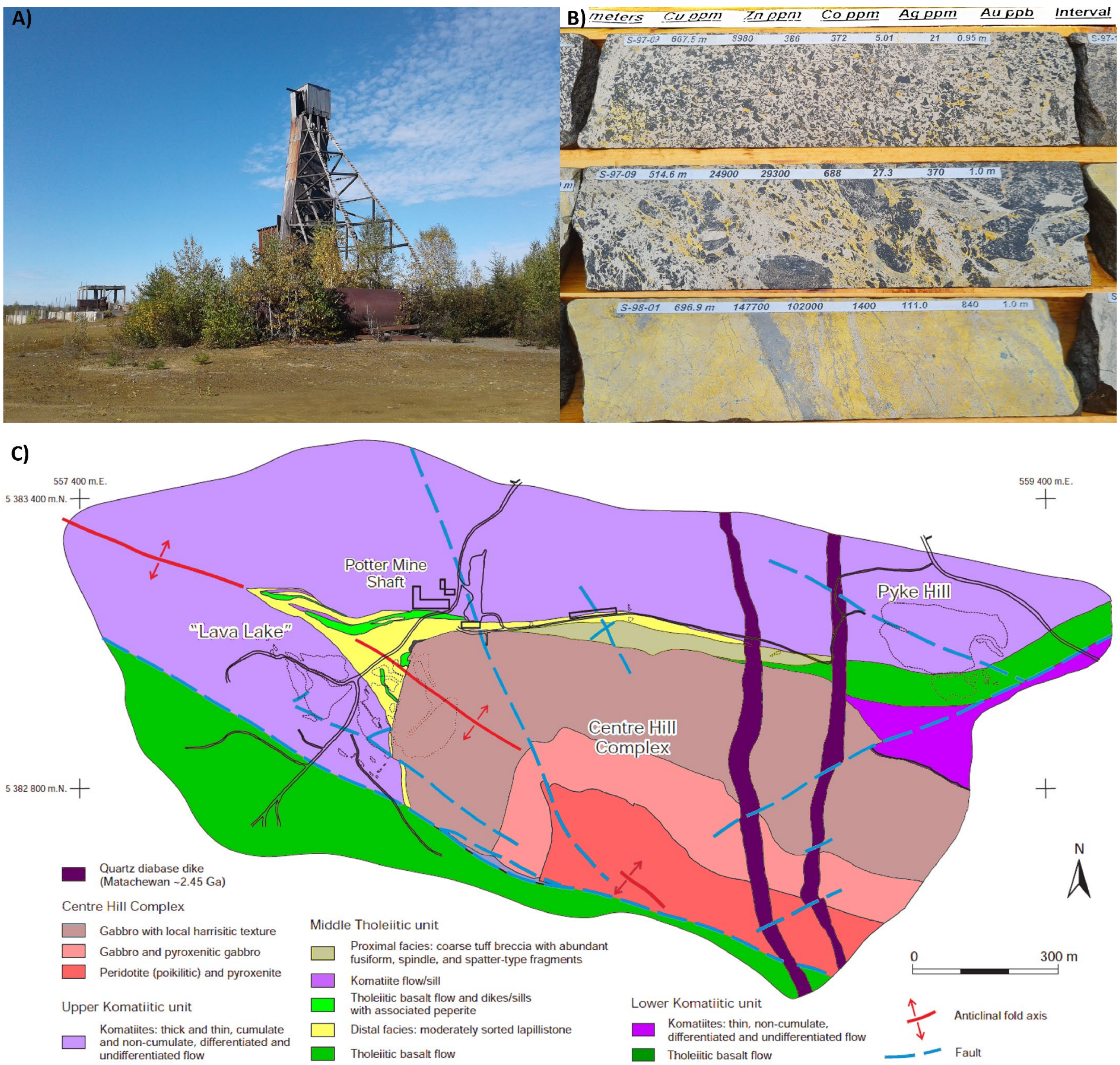

Figure 6. **A)** Old Shaft at Stop 2-2. **B)** NQ drill core photographs and assays. **C)** Geological map of the Potter Mine area (*modified from* Houlé, Lesher and Préfontaine 2017).

Stop 2-3. Diamictite, Huronian Supergroup

UTM 559610E 5327980N

Potential hazards:

- Steep and/or slippery slopes; loose rocks
- Busy road with high-speed traffic; stay off road shoulder and remain away from parked vehicles if possible; high-visibility vests required

The Huronian Supergroup (2446–2218 Ma) is a rift to passive margin basin deposit that overlies the southeastern margin of the Superior Province (Long 2004). Outliers of the Huronian Supergroup are present in various locations in the Abitibi greenstone belt. The stop is located on Highway 11, 200 m southwest of the Kenogami Bridge. The outcrop is a diamictite of the Gowganda Formation (*circa* 2340 Ma) (Photo 6).

Photo 6. Photograph of diamictite of the Gowganda Formation at Stop 2-3 (the outcrop shown in the image is ~2 m wide).

Stop 2-4. Metaconglomerate, Timiskaming assemblage

UTM 569660E 5332380N

Potential hazards:

- Steep and/or slippery slopes; loose rocks
- Busy road with high-speed traffic; stay off road shoulder and remain away from parked vehicles if possible; high-visibility vests required

This roadcut, adjacent to the Agnico Eagle Mines Limited Macassa Mine (Photo 7A) on Highway 66 on the west side of Kirkland Lake, exposes a sequence of massive to diffusely stratified polymictic metaconglomerate and interbedded metasandstone (Photo 7B), representing the "conglomerate-sandstone facies association" of the Timiskaming assemblage defined by Mueller, Donaldson and Doucet (1994). The conglomerate vary locally from matrix- to clast-supported and consist of cobble to boulder-size clasts of volcaniclastic rocks, gneiss, basalt, quartz-feldspar porphyry, feldspar porphyry, pseudoleucite porphyry, and red jasper. Erosive contacts between the conglomerate and the underlying sandstone beds are also common. The sandstone beds are typically coarse- to very coarse-grained and variably preserve trough cross-beds, planar beds and planar cross-beds.

The Timiskaming assemblage sedimentary rocks are interpreted to represent deposition in a stream-dominated alluvial fan or a braided river proximal to major faults (Mueller, Donaldson and Doucet 1994). Their fluvial nature contrasts with the older sedimentary basins in the Abitibi greenstone belt, which were deposited in an interpreted marine environment.

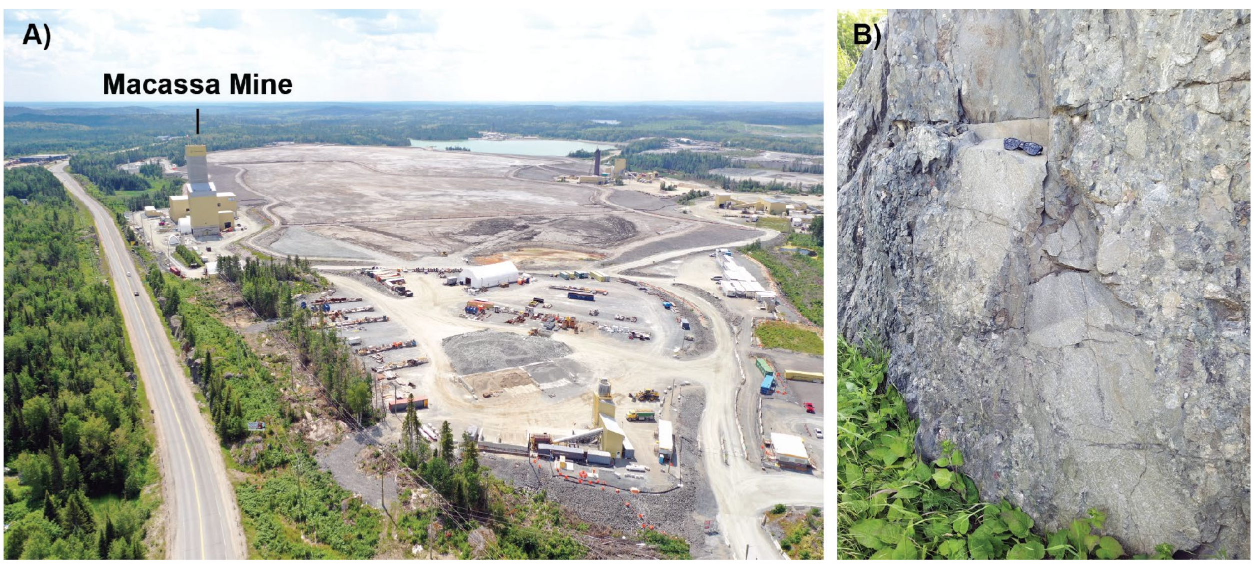

Photo 7. A) Macassa Mine (aerial photograph). **B)** Timiskaming assemblage metaconglomerate at Stop 2-4 (the outcrop shown in the image is ~2 m wide).

Stop 2-5. Discovery outcrop

UTM 571990E 5333900N

Potential hazards:

- Steep and/or slippery slopes; loose rocks
- Business area, watch for local traffic
- Adjacent to a busy road; stay off road shoulder and remain away from parked vehicles if possible; high-visibility vests required

The Discovery outcrop is located east of Tweedsmuir Road in Kirkland Lake beside the Ontario Ministry of Children and Youth Services Building. It consists predominantly of a syenite porphyry, a gold-bearing quartz vein, and a cataclastic band along the margin of the vein. The vein is interpreted to reflect the main east- and west-trending break or fault that hosts the majority of gold mineralization in the Kirkland Lake gold camp. A 0.5 m interval of strongly foliated syenite porphyry, immediately adjacent to the quartz vein, strikes parallel to the main break (Photo 8).

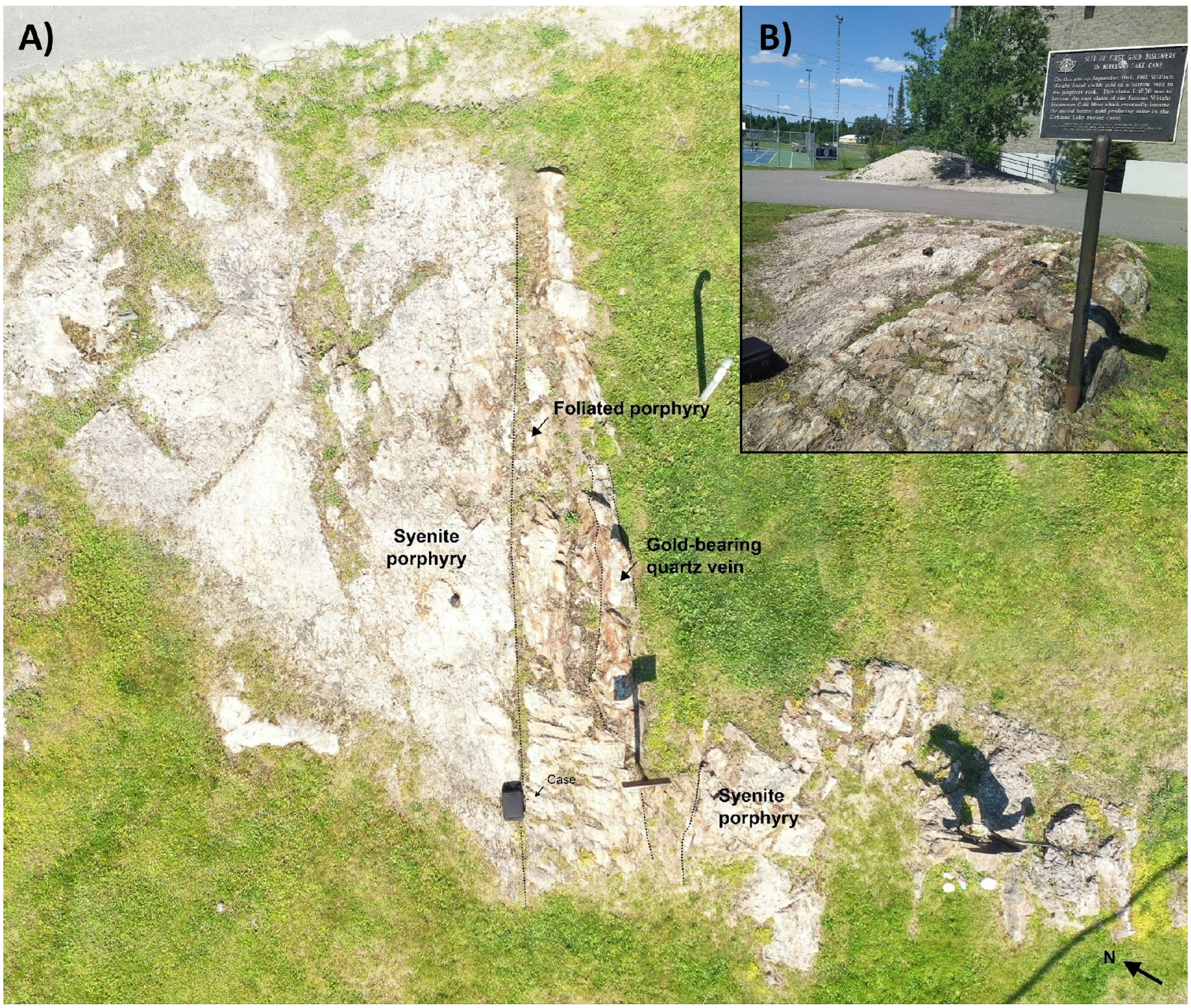

Photo 8. Discovery outcrop area at Stop 2-5. **A)** Drone imagery with geological interpretation. **B)** Photograph of the Discovery site plaque and the host foliated syenite porphyry.

Stop 2-6. Alkalic metavolcaniclastic rocks, Timiskaming assemblage

UTM 571550E 5334350N

Potential hazards:

- Steep and/or slippery slopes; loose rocks
- Parking is by a busy road with high speed traffic; stay off road shoulder and remain away from parked vehicles if possible; high-visibility vests required
- Requires a hike along a powerline to reach the outcrop

The Powerline outcrop is located approximately 200 m east of Goodfish Road in Kirkland Lake, between Brant Avenue and Simms Road (Figure 7). It was originally mapped by Mueller, Donaldson and Doucet (1994) and then later by Hufford (2015). The outcrop consists of metamorphosed beds of tuff and lapilli tuff (and multiple interbedded breccia horizons) that reflect deposition from phreatomagmatic pyroclastic base surges. Individual units are generally poorly to moderately sorted and are massive, or preserve low-angle cross-bedding, wavy bedding, and planar laminations (Muller, Donaldson and Doucet 1994) (Photo 9). The tops of individual beds are also commonly scoured, reflecting erosion by subsequent pyroclastic surges. Ballistic fragments of trachytic "pumice" and red syenite are common toward the base of the sequence, whereas accretionary lapilli (indicative of water in the eruption column) are locally preserved toward the top of the sequence. The location of the original vents is unknown.

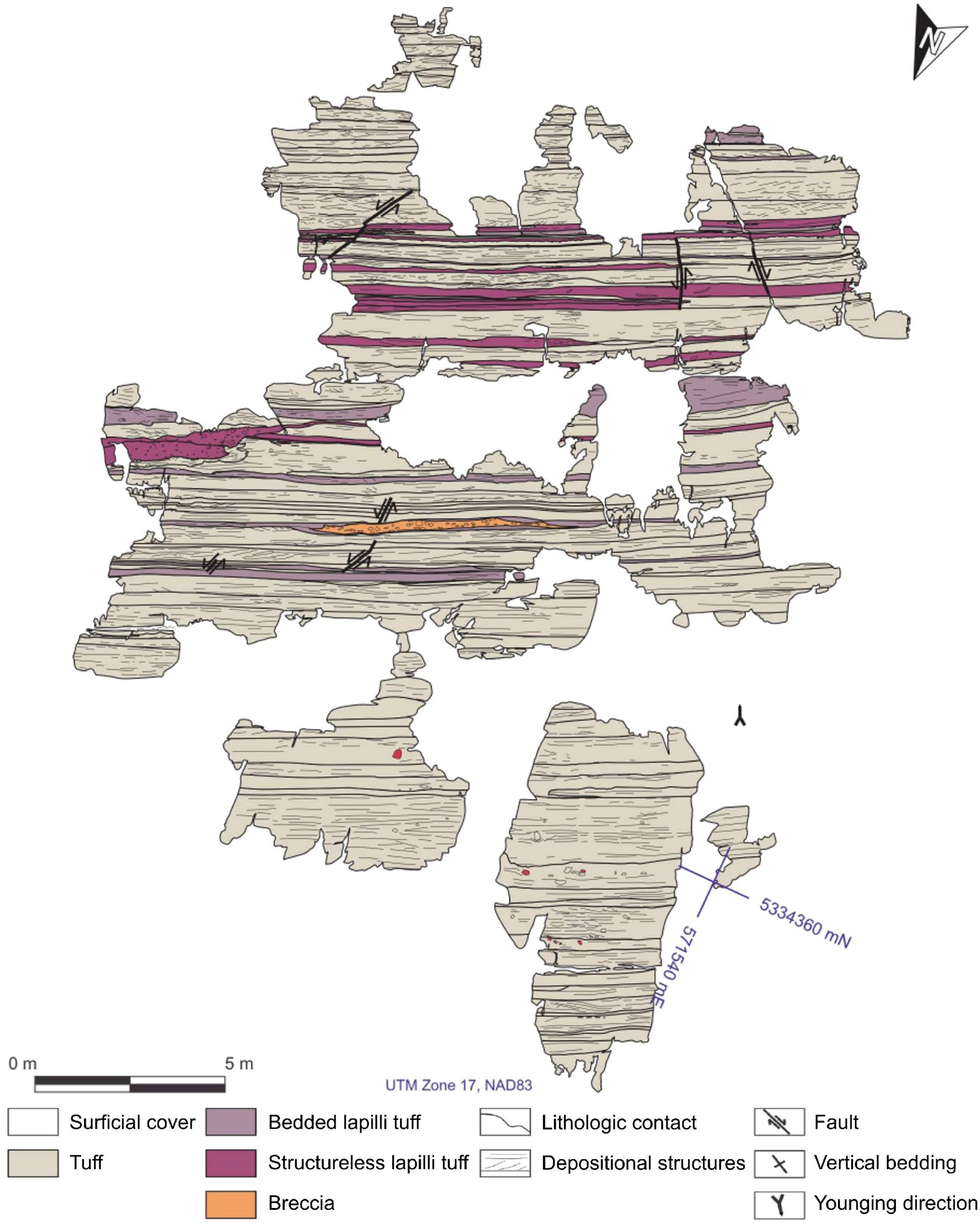

Figure 7. Simplified geological map of the Powerline outcrop at Stop 2-6, depicting a succession of pyroclastic base surges (*modified from* Hufford 2015).

Photo 9. Photographs of Timiskaming assemblage volcaniclastic units at Stop 2-6: **A)** and **B)** ballistic blocks; **C)** breccia; **D)** faulted stratigraphy; **E)** pyroclastic fall(?) and base surge deposits; and **F)** accretionary lapilli (the pen, for scale in all photos, is 8 mm wide).

Stop 2-7. Alkalic intrusive rocks, Timiskaming assemblage

UTM 570830E 5333040N

Potential hazards:

- Steep and/or slippery slopes; loose rocks
- Business area, watch for local traffic; if possible, park in the Veteran's Affairs Building parking lot and walk to the outcrop; high-visibility vests required

The Don Lou outcrop is located south of Government Road East in Kirkland Lake, adjacent to the Kirkland Lake Veteran's Affairs Building at 8 Oakes Avenue. It consists of metavolcaniclastic rocks, augite syenite, feldspar syenite, and a feldspar-phyric dike (Photo 10). The metavolcaniclastic unit, which is preserved on the south side of the outcrop, consists of bedded tuff and lapilli tuff (Hufford 2015). The bedding is locally truncated by the augite syenite, which intruded the metavolcanic rocks. The augite syenite was subsequently intruded by feldspar syenite that defines a series of semi-parallel east-trending rhythmic layers that decrease in spacing toward the south. The thickness of the layers also decreases toward the south. The feldspar-phyric dike, located on the north side of the outcrop, crosscuts both the augite syenite and the feldspar syenite. The dike is irregular in shape, thickens toward the northwest and contains multiple xenoliths seemingly derived from the underlying basement rock (Hufford 2015).

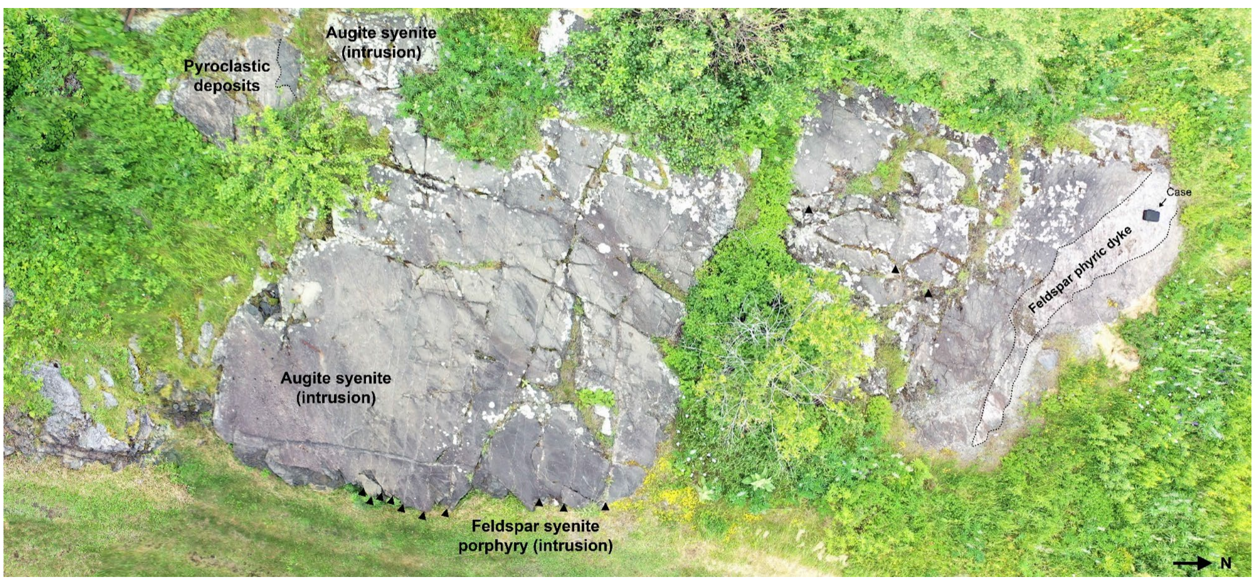

Photo 10. Drone imagery of Timiskaming assemblage alkalic intrusive rocks at Stop 2-7. The image is annotated with geological interpretation.

Stop 2-8. Alkalic intrusive rocks, Timiskaming assemblage

UTM 570920E 5332710N

Potential hazards:

- Steep and/or slippery slopes; loose rocks
- Business area, watch for local traffic
- Stay on marked trail

The Kinross Pond outcrop is located 300 m south of the Don Lou outcrop in Kirkland Lake. It was exposed during the construction of a walking trail in 2012, was mapped by Hufford (2015) and Hufford and Monecke (2019), and displays south-facing (younging to the left) Timiskaming assemblage polymictic metaconglomerate, interbedded metasandstone and a post-depositional augite syenite that intruded the metasedimentary succession (Photo 11). The augite syenite dike crosscuts the Timiskaming assemblage metasedimentary rocks at a relatively high angle on the east side of the outcrop. Branching sills of augite syenite on the north to northwest side of the outcrop are parallel to bedding and terminate within the succession (Hufford and Monecke 2019). A feldspar syenite dike that crosscuts Timiskaming assemblage polymictic metaconglomerate occurs on the north to northeast side of the outcrop (Hufford 2015; Hufford and Monecke 2019).

Photo 11. Drone imagery of alkalic intrusive rocks and Timiskaming assemblage metaconglomerate at Stop 2-8. The image is annotated with geological interpretation.

DAY 3. LARDER LAKE MINING CAMP AND NORANDA MINING CAMP

Stop 3-1: Alkalic metavolcaniclastic rocks, Timiskaming assemblage (581230E 5332900N)
Stop 3-2: Larder Lake–Cadillac deformation zone (591970E 5328770N)
Stop 3-3: Kerr-Addison Mine (605500E 5332400N)
Drive to Rouyn Noranda
Stop 3-4: Massive and pillowed flows, Blake River assemblage (648100E 5344220N)
Stop 3-5: Glenwood metarhyolite, Blake River assemblage (648190E 5343080N)
Stop 3-6: Metakomatiites, Kidd–Munro assemblage (712740E 5361550N)
Day ends in Val d'Or

Stop 3-1. Pseudoleucite flows and metavolcaniclastic rocks, Timiskaming assemblage

UTM 581230E 5332900N

Potential hazards:

- Steep and/or slippery slopes; loose rocks
- Busy road with high-speed traffic; stay off road shoulder and remain away from parked vehicles if possible; high-visibility vests required

This stop near Crystal Lake, located on Highway 66 between Kirkland Lake and Larder Lake, shows a coherent flow with pseudoleucite (mixture of orthoclase and nepheline pseudomorphic after leucite). Pseudoleucite crystals range up to 2 cm and can comprise up to 90% of the rock.

Volcanic rocks of the Timiskaming assemblage are intercalated within the dominantly metasedimentary succession (Photo 12). The volcanic intervals are repeated at several intervals in the stratigraphy and range from calc-alkalic to alkalic in composition. The composition of the volcanic rocks became more alkalic and explosive during the closing stages of each volcanic cycle (Cooke and Moorhouse 1969).

Photo 12. Photograph of alkalic metavolcaniclastic rocks of the Timiskaming assemblage in the roadcut on Highway 66 at Stop 3-1.

Stop 3-2. Larder Lake–Cadillac deformation zone

UTM 591970E 5328770N

Potential hazards:

- Steep and/or slippery slopes; loose rocks
- Busy road with high-speed traffic; stay off road shoulder and remain away from parked vehicles if possible; high-visibility vests required

One of the best roadside exposures of fuchsite alteration is located in a roadcut 3.5 km west of Larder Lake on Highway 66. Highly strained rocks of the Larder Lake–Cadillac deformation zone are visible west of the roadcut (Photo 13).

Photo 13. Photograph of fuchsite alteration (greenish) next to intrusive rocks (pinkish) at Stop 3-2 on Highway 66 west of Larder Lake.

Stop 3-3. Kerr-Addison Mine

UTM 605500E 5332400N

Caution: Access requires permission from Gold Candle Ltd. and wearing of steel-toed boots, high-visibility vests, safety glasses and hard hats. The company may stipulate other conditions for access.

Historically, the Kerr-Addison Mine is Canada's fifth largest individual gold mine and, between 1938 and 1996, the Kerr-Addison Mine and Chesterville Mine collectively produced more than 11 million ounces of gold (Kerr-Addison: 35.3 Mt grading 9.1 g/t Au; Chesterville: 2.96 Mt grading 3.8 g/t Au) (Smith et al. 1993). Almost all of the historical production was completed using underground extraction methods.

The Larder Lake–Cadillac deformation zone (LLCDZ), on which the Kerr-Addison Mine property is located, strikes generally east-northeast, dips steeply to the north, and extends approximately 250 km from Matachewan, Ontario, to Val d'Or, Québec. The Kerr-Addison Mine property is in the immediate structural footwall of the LLCDZ, hosted by ultramafic and mafic metavolcanic rocks or the Larder Lake Group (Figures 8 and 9). Kerr-Addison is an orogenic gold deposit, which formed broadly synchronous with deformation, metamorphism and magmatism during lithospheric-scale continental-margin orogeny. Both deposits are located adjacent to first-order, deep crustal fault zones, which show complex structural histories and may extend along strike for hundreds of kilometres. Fluid migration along such zones was

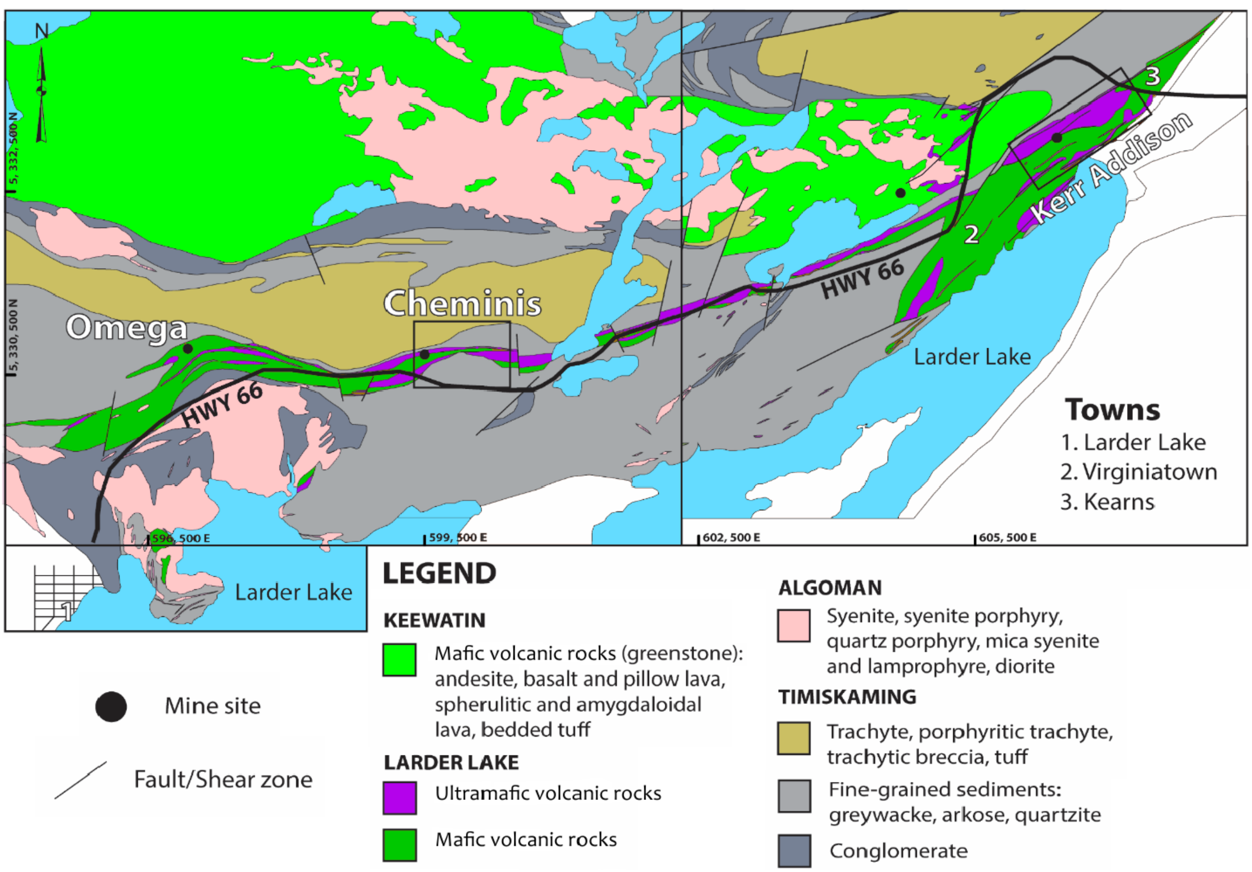

Figure 8. Regional geological map for the area between Larder Lake and the Kerr-Addison Mine (*modified from* Thomson 1943).

driven by episodes of major pressure fluctuations during seismic events, and gold mineralization formed as vein-fill of second- and third-order shears and faults, particularly at jogs or changes in the strike along the crustal fault zones. Mineralization styles vary from stockworks and breccias in shallow, brittle regimes, through laminated crack-seal vein and sigmoidal vein arrays in brittle–ductile crustal regions, to replacement- and disseminated-type orebodies in deeper, ductile environments.

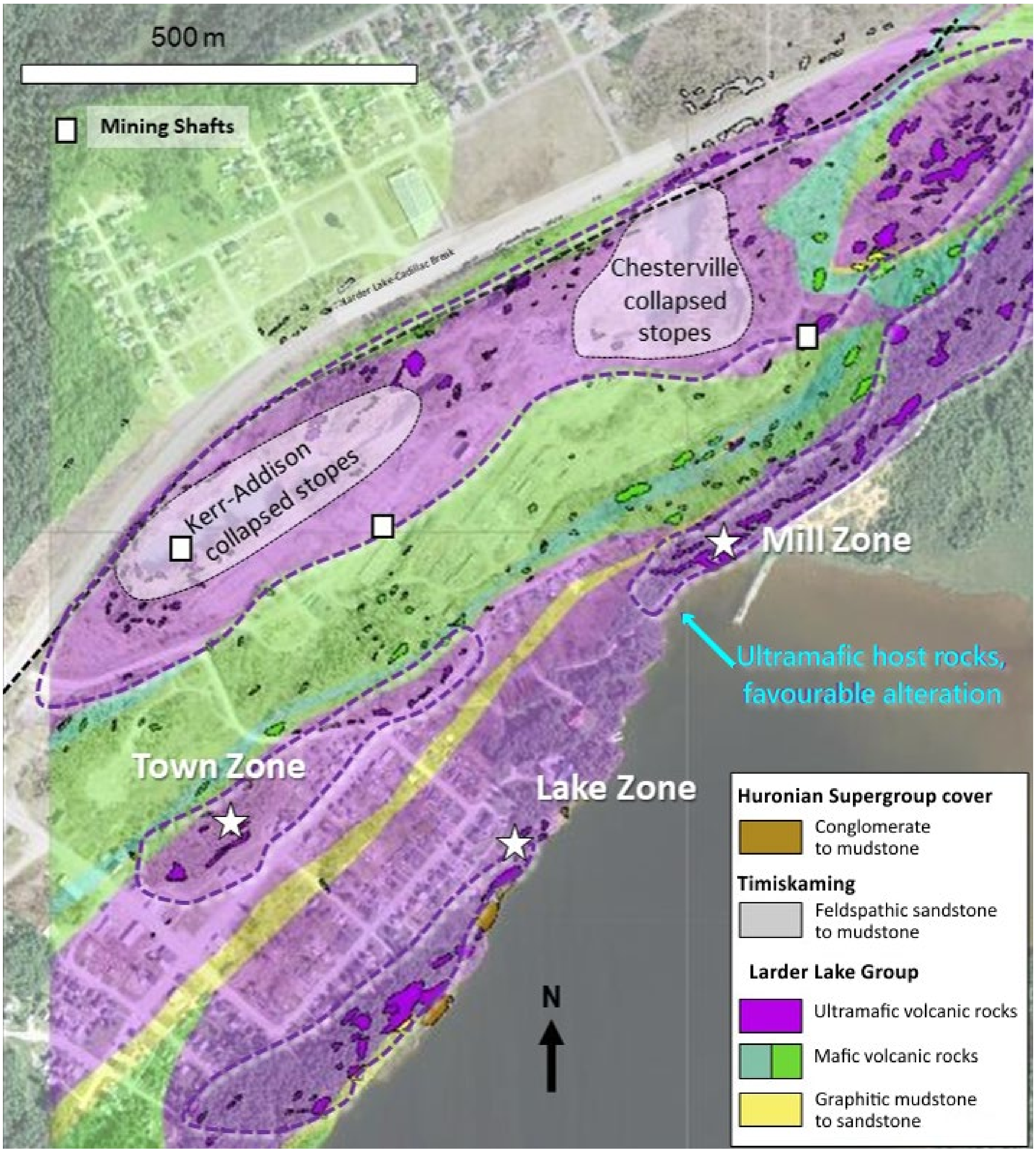

Figure 9. Aerial image of Kerr-Addison Mine property, at Stop 3-3, overlain with surface geology and locations of mineralized zones, mine shafts and stopes (*modified from* Thompson 1943).

Stop 3-4. Massive and pillowed flows, Blake River assemblage

UTM 648100E 5344220N

Potential hazards:

- Steep and/or slippery slopes; loose rocks
- Stay on marked trail; park vehicles at trail head; high-visibility vests required

The first outcrop at this stop is a sequence of massive metabasaltic flows with associated flow-top breccias. Flow-top breccia forms by autobrecciation of lava during flow advance. Pay close attention to the contact relationships between the breccias and the massive flows. Flows have irregular and/or gradational contacts with their associated flow-top breccia and a sharp, chilled contact with the flow-top breccia of underlying flows. Use these contact relationships to determine which way is "up", or the "younging direction". Younging direction is important in establishing the stratigraphy of a volcanic sequence. Stratigraphy is critical for VMS exploration because VMS deposits have a strong stratigraphic control. Now look at the matrix of the flow-top breccia and take note of the texture. You should see fragments with sharp, cuspate margins. This is a textbook example of hyaloclastite. Hyaloclastite is a product of quench fragmentation that occurs when hot lava comes into contact with cold seawater (Figure 10). This texture is unequivocal evidence for a subaqueous paleoenvironment.

The second outcrop is located approximately 40 m farther along the trail. It shows another sequence of metabasaltic flows, but these flows are pillowed rather than massive. Pillow forms can also be used to determine younging. Pillows have a pointed "tail" at their base, and round or flat tops. Amygdules are typically concentrated toward the top of the pillow. The dark, glassy rim around a pillow is called a selvage. Look for hyaloclastite in the pillow selvages. Pillows are interconnected lava tubes that form in a way that is similar to the way subaerial pahoehoe lava is formed. You are looking at a cross section through the lava tubes, which makes them look like discrete entities (*see* Figure 10). Smaller pillow tubes can be fed by larger tubes or "lava rivers". Look for the largest lava tube you can find.

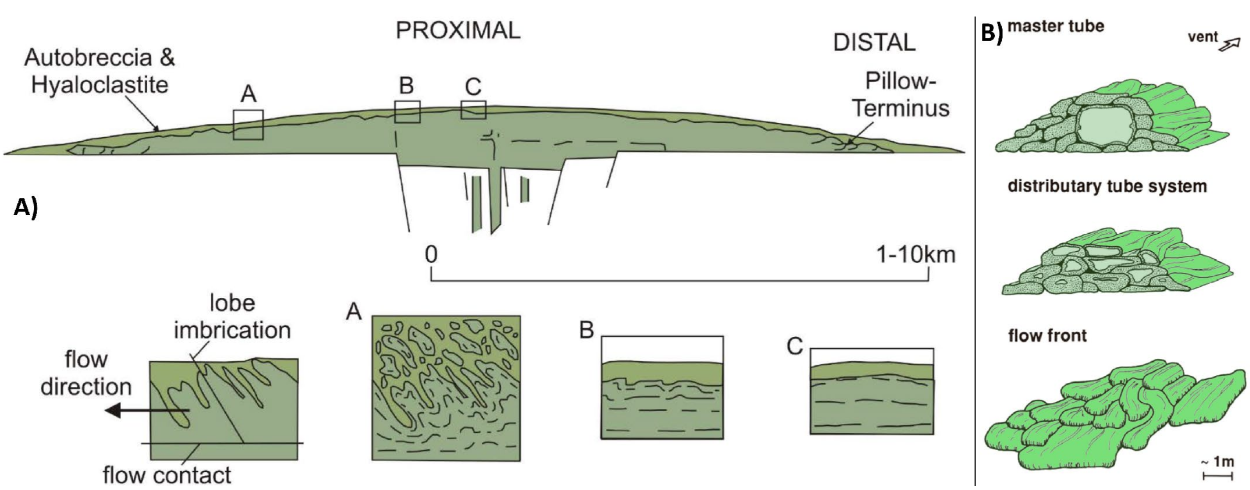

Figure 10. Diagrams showing the flow facies present in mafic volcanic systems, such as those observed at Stop 3-4. **A)** Massive flow facies (*modified from* Gibson, Morton and Hudak 1999). **B)** Pillow flows (*modified from* Rowland and Walker 1990).

Stop 3-5. Glenwood metarhyolite, Blake River assemblage

UTM 648190E 5343080N

Potential hazards:

- Steep and/or slippery slopes; loose rocks
- In town off Rue Lapointe, a busy road; stay off road shoulder and remain away from parked vehicles if possible; high-visibility vests required
- Requires a short walk uphill from Lapointe Park to reach the outcrop

This outcrop is dominantly a felsic metavolcaniclastic unit. Look at the size and composition of the clasts. How many different clast types do you see? Use the volcaniclastic classification diagram (Figure 11) to classify this rock. Look for bedding defined by clast size and clast content.

This is a bedded, monolithic felsic tuff breccia. The bedding (although cryptic) tells us that the clasts have been transported from their source because transport is required to sort the clasts. However, the monolithic nature of this unit tells us that it has a single source (provenance) and, therefore, the clasts must not have been transported far. This unit likely formed by over-steepening and collapse of a felsic lava dome. Volcanogenic massive sulphide deposits in bimodal sequences (mafic and felsic, no intermediate rocks) are commonly associated with felsic rocks, and this rock type is very prospective in exploration because it tells us that we are close to a felsic dome and a volcanic vent.

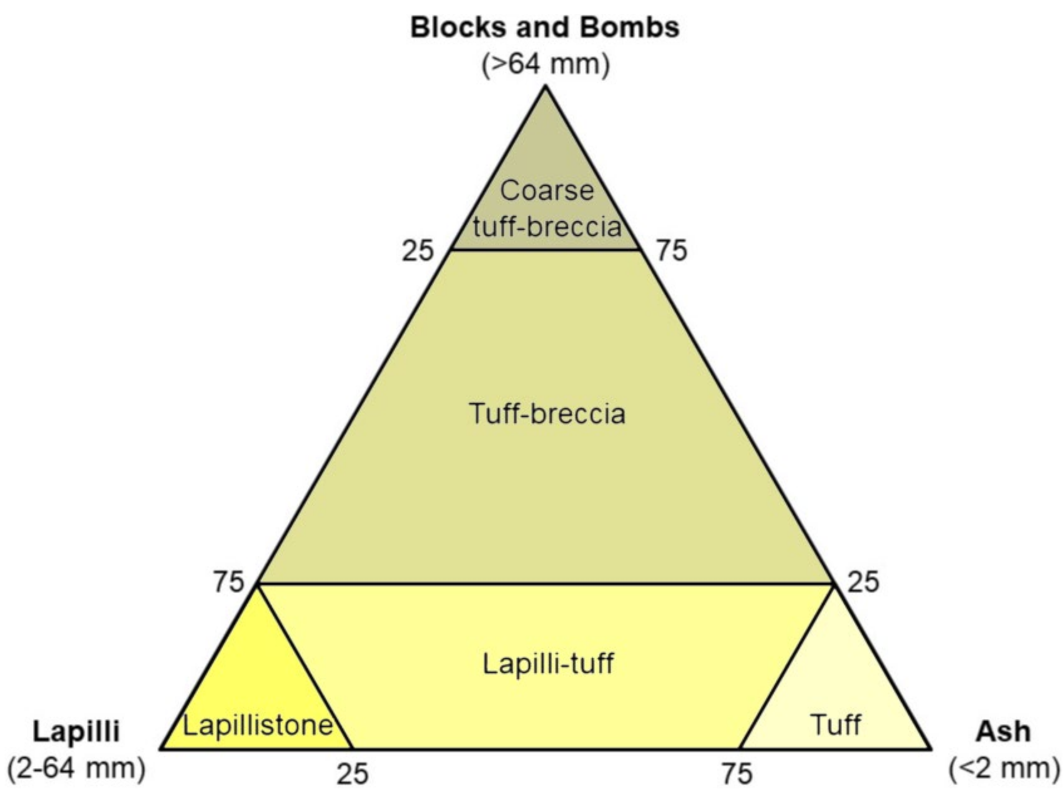

Figure 11. Classification scheme for volcaniclastic rocks (*modified from* Schmid 1981, *modified from* Fisher 1966).

Stop 3-6. Metakomatiites, Kidd–Munro assemblage

UTM 712740E 5361550N

Potential hazards:

- Steep and/or slippery slopes; loose rocks
- Busy road with high-speed traffic; stay off road shoulder and remain away from parked vehicles if possible; high-visibility vests required

Similar to Pyke's Hill (Stop 2-1), the Canadian "Spinifex Ridge" outcrop displays a series of very well-preserved metakomatiite flows (Figure 12), also part of the Kidd–Munro assemblage (2720–2710 Ma; Frieman et al. 2017). A detailed description of the outcrop is provided by Houlé et al. (2017, and references therein). The stop is located east of Highway 109 in Québec, 17 km north of Rivière Héva.

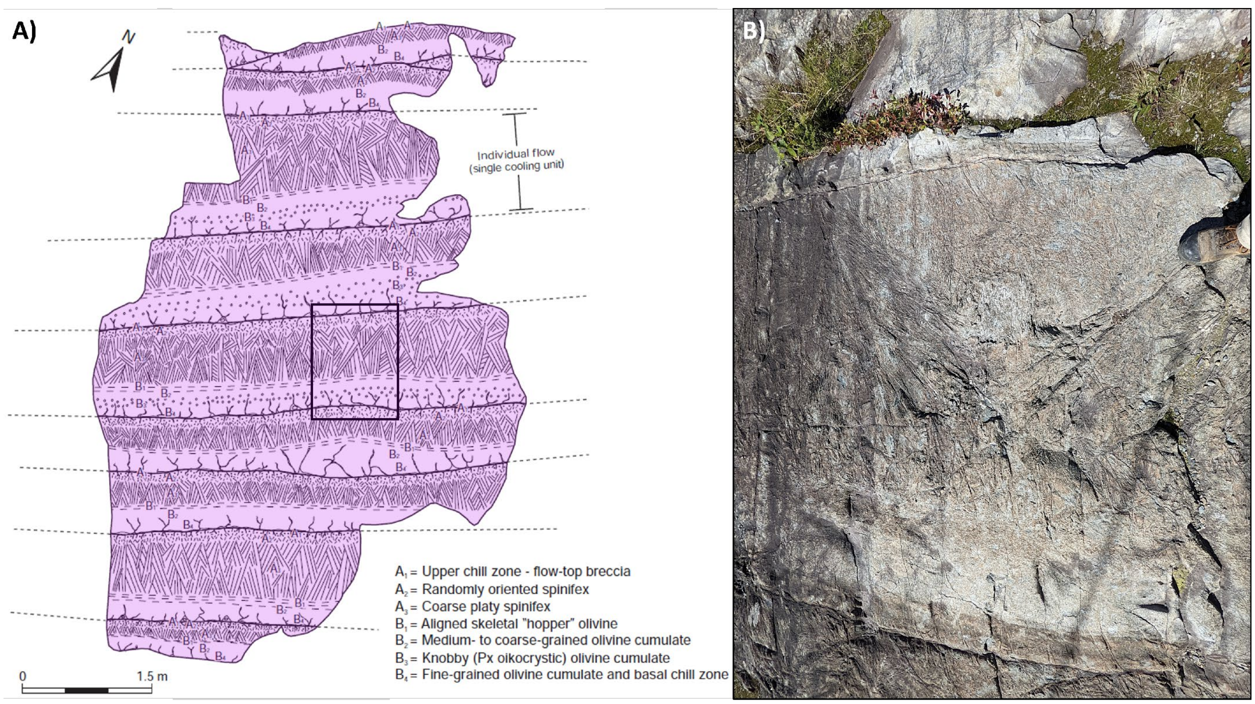

Figure 12. A) Geological map of the Spinifex Ridge west outcrop (Stop 3-6) (map *modified from* Houlé, Lesher and Préfontaine 2017, *modified from* Champagne 2004). Abbreviation: Px, pyroxene. **B)** Photograph of the metakomatiite flows at Stop 3-6 (the outcrop shown in the image is ~1 m wide).

DAY 4. VAL D'OR MINING CAMP AND MALARTIC MINING CAMP

All stops on Day 4 are provided in NAD83, Zone 18N. For continuity, extended Zone 17N co-ordinates are also provided with each stop description.

Stop 4-1: Sigma Mine: Drill-core viewing of Ormaque and Triangle deposits
(295049E 5331005N, Zone 18; 741740E 5332440N, Zone 17) (requires permission to visit)
Stop 4-2: Canadian Malartic pit lookout
(267583E 5335830N, Zone 18; 713980E 5335110N, Zone 17)
Stop 4-3: Canadian Malartic Cartier Zone
(264469E 5337568N, Zone 18; 710740E 5336600N, Zone 17) (requires permission to visit)
Stop 4-4: Canadian Malartic pit tour and drill-core viewing
(266320E 5333531N, Zone 18; 712900E 5332720N, Zone 17) (requires permission to visit)
Stop 4-5: Metagreywacke, Pontiac Subprovince
(264815E 5335595N, Zone 18; 711240E 5334650N, Zone 17)
Stop 4-6: Metagreywacke, Pontiac Subprovince
(262875E 5333098N, Zone 18; 709500E 5332020N, Zone 17)
End of Field Trip

Stop 4-1. Sigma Mine: Drill-core viewing of Ormaque and Triangle deposits

UTM 295049E 5331005N, Zone 18N;
UTM 741740E 5332440N, Zone 17N

Caution: Access requires permission from Eldorado Gold Corporation and wearing of steel-toed boots, high-visibility vests, safety glasses and hard hats. The company may stipulate other conditions for access.

The Sigma-Lamaque deposit (~14 Moz of gold; Dubé and Mercier-Langevin 2020) is the landmark in the Val d'Or mining camp and one of the best-known Archean orogenic gold systems. It was extensively investigated by Robert and Brown (1986) and Robert (1994). It is hosted primarily by mafic metavolcanic rocks equivalent in age to the Tisdale assemblage (2710–2704 Ma; Frieman et al. 2017) and crosscut by feldspar-porphyry dikes (2704 and 2695–2685 Ma) (Figure 13). The new Triangle and Ormaque deposits, and the Sigma-Lamaque deposit are all part of the same mineralizing system (*see* Figure 13). The local geology and mineralization are documented by Simoneau et al. (2021).

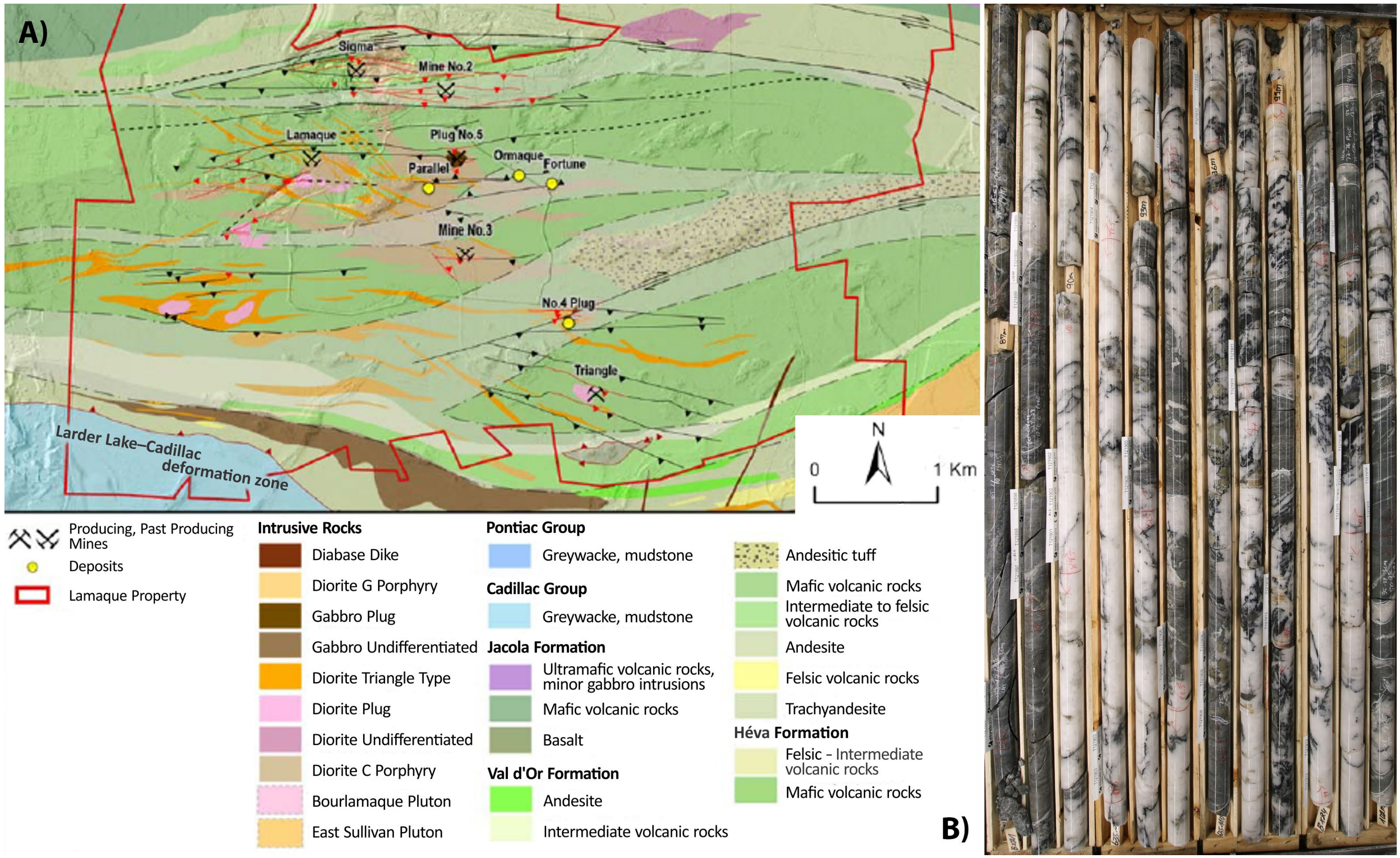

Figure 13. **A)** Geological map of the Sigma Mine area (*modified from* Simoneau et al. 2021). **B)** Drill core (NQ size) of a thick quartz-carbonate-tourmaline vein (Triangle deposit) related to Stop 4-1.

Stop 4-2. Canadian Malartic pit lookout

UTM 267583E 5335830N, Zone 18N;
UTM 713980E 5335110N, Zone 17N

Potential hazards:

- Steep and/or slippery slopes; loose rocks
- Lookout is in town, on the south side of Rue de la Paix; high-visibility vests required

The Agnico Eagle Mines Limited Canadian Malartic pit is the largest open pit gold mine in Canada. It is 2 km long (3.5 km including the new westward extension) (Photo 14A), 1 km wide and 0.4 km deep (Photo 14B). The lookout is located on the south side of the town, near the Mineralogy Museum.

Photo 14A. Panoramic view of the Canadian Malartic pit (view toward the west) taken from the lookout at Stop 4-2.

Photo 14B. Aerial view of the Canadian Malartic pit (view toward the west). Image *from* Google Earth™ mapping service, image © 2022 Maxar Technologies.

Stop 4-3. Canadian Malartic Cartier Zone

UTM 264469E 5337568N, Zone 18N;
UTM 710740E 5336600N, Zone 17N

Caution: Access requires permission from Agnico Eagle Mines Limited and wearing of steel-toed boots, high-visibility vests, safety glasses and hard hats. The company may stipulate other conditions for access.

The Cartier Zone is located 3 km north-west of the Canadian Malartic pit. The exposure has been known since 1923, when a junior company named "Cartier Malartic Gold Mines" built a shaft with the belief that the zone was mineralized like Canadian Malartic. Previous studies in that area were conducted by Gunning and Ambrose (1940) and Neumayr, Hagemann and Couture (2000). A BSc thesis (Blacklock 2015) aimed to characterize the multiple generation of veins that can be identified in the Cartier area.

The outcrop (Figures 14A, 14B and 14C) consists of the hinge of a hectometre-scale S-shaped tight F_2 fold of a 100 m thick monzodiorite dike (*circa* 2678 Ma). Variations of the bedding orientation and polarity in the host metasedimentary rocks suggest the presence of older, tight to isoclinal, F_1 folds. Local observations of subhorizontal bedding support the interpretation of an F_1 and F_2 hinge zones interference zone. The monzodiorite dike intruded the area during late D_1 to early D_2 deformation events. Large, metre-scale, barren white quartz veins filled openings during D_2 folding. Vuggy quartz-carbonate veins, associated alteration and minor gold mineralization are visible on the southeast part of the outcrop.

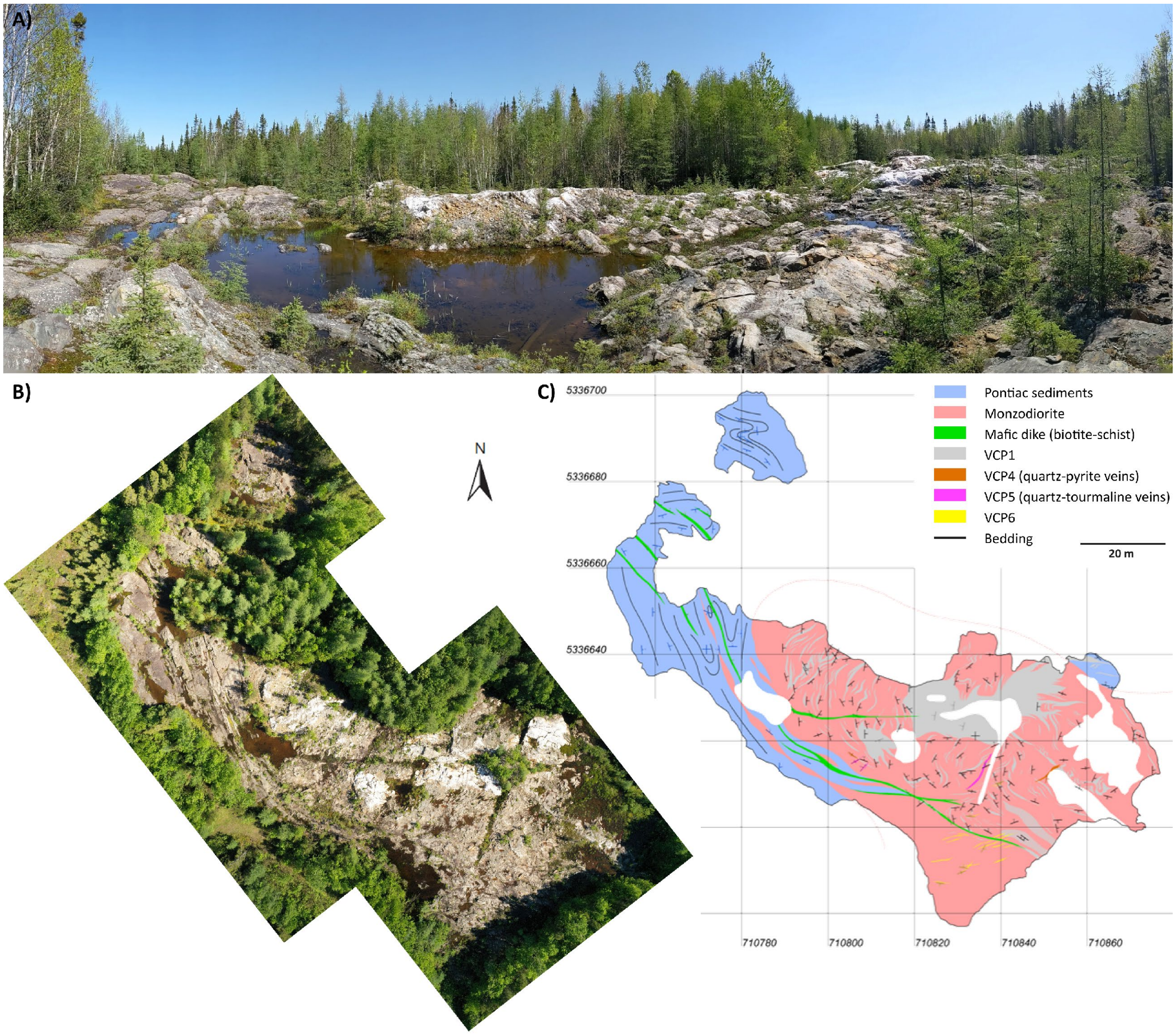

Figure 14. A) Photograph of the stripped exposure at Stop 4-3. **B)** Drone imagery of the stripped exposure at Stop 4-3. **C)** Geological map of the stripped exposure (*modified from* Blacklock 2015).

Stop 4-4. Canadian Malartic pit tour and drill-core viewing

UTM 266320E 5333531N, Zone 18N;
UTM 712900E 5332720N, Zone 17N

Caution: Access requires permission from Agnico Eagle Mines Limited and wearing of steel-toed boots, high-visibility vests, safety glasses and hard hats. The company may stipulate other conditions for access.

The Mineralogy Museum of Malartic also organizes mine visits on a daily basis (*see* www.museemalartic.qc.ca/en for more information).

The Canadian Malartic deposit (~25.9 Moz of gold) and its metasomatic halo was extensively investigated by both Target Geoscience Initiative (TGI-4) and Canadian Mining Innovation Council-Natural Sciences and Engineering Research Council (CMIC–NSERC) Footprints programs between 2013 and 2018. One of the most recent publications by De Souza et al. (2020, and references therein), outlines the key characteristics of this major stockwork-disseminated gold system (Figure 15).

Canadian Malartic gold mineralization is primarily controlled by the Sladen fault zone that branches out of the Larder Lake–Cadillac deformation zone and lies along the contact between quartz-monzodiorite and monzonite dikes that are visible on the northern wall of the pit. The eastern and western extent of this south-dipping fault zone can be seen on the mine wall, mainly outlined with pervasive biotite, microcline, albite, calcite, ferroan-dolomite, pyrite and quartz alteration, which results in a lighter or tan colouration of the host metasedimentary rocks. Additionally, a couple of galleries from the historical underground mines are visible on the eastern wall. The bulk of the mineralization crops out at the surface to the west of the pit and then plunges toward the east at approximately 10 to 30° for over 5 km, beyond the new Odyssey underground mine. South of the pit, F_2 fold hinges acted as second-order traps that host part of the low-grade mineralization envelope.

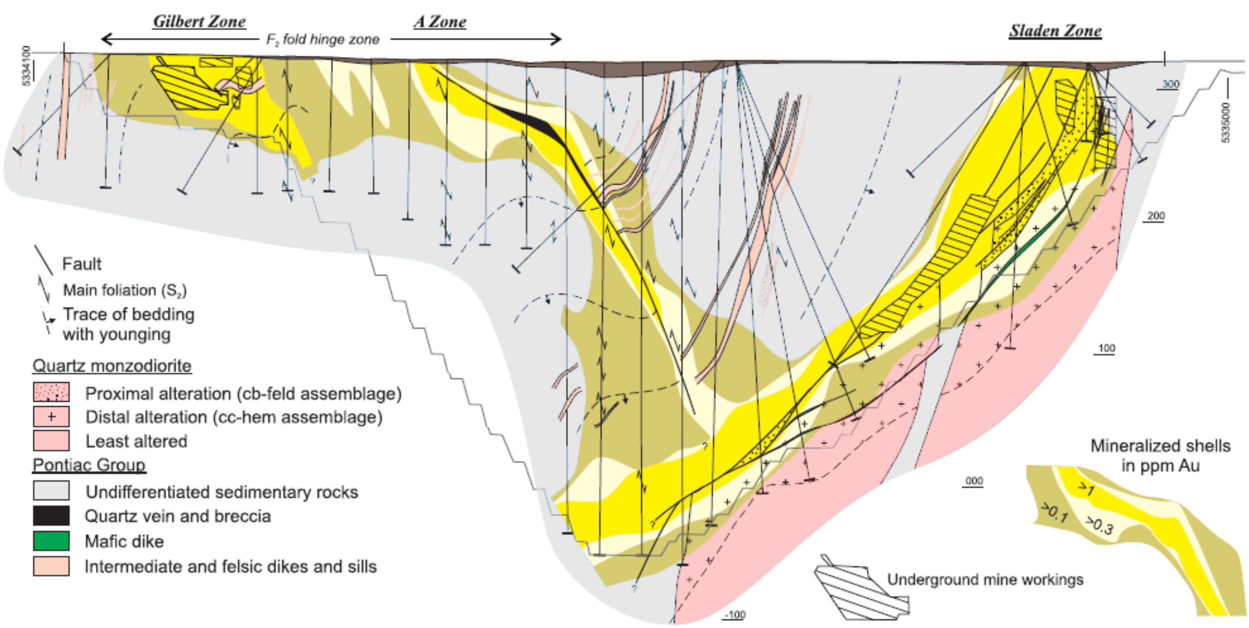

Figure 15. South to north cross section across the Canadian Malartic pit at Stop 4-4 (*modified from* De Souza et al. 2020). Underground workings of past-producing mines are shown in hatched pattern and main ore zones are identified in italic. Abbreviations: cb-feld, carbonate-feldspar; cc-hem, calcite-hematite. The UTM co-ordinates are provided using NAD83 in Zone 17.

Stop 4-5. Metagreywacke, Pontiac Subprovince

UTM 264815E 5335595N, Zone 18N;
UTM 711240E 5334650N, Zone 17N

Potential hazards:

- Steep and/or slippery slopes; loose rocks
- Stay off road shoulder and remain away from parked vehicles if possible; high-visibility vests required

The outcrop is located 2 km west of the Canadian Malartic pit. Metasedimentary rocks of the Pontiac Group include (meta-) greywacke, sandstone, siltstone and mudstone with rare graphitic horizons, similar to the Porcupine assemblage (2690–2685 Ma; Frieman et al. 2017). Sedimentary beds, cross-beds, and a subtle crosscutting northwest-trending foliation outlined by biotite are visible throughout the outcrop (Photo 15).

Pyrite grains are locally present and commonly display synsedimentary and/or diagenetic nucleus overgrown by one or more hydrothermal stages. Pyrrhotite replacement of pyrite is common with increasing metamorphism toward the south in the Pontiac Subprovince. Although the outcrop does not display clear evidence of hydrothermal alteration to the naked eye, still, it is located within the metasomatic halo of the Canadian Malartic system, based on the mineral chemistry of biotite and white mica grains at this locality (Lypaczewski et al. 2020).

Photo 15. Photograph of metagreywacke of the Pontiac Group at Stop 4-5 (the outcrop shown in the image is ~1 m wide).

Stop 4-6. Metagreywacke, Pontiac Subprovince

UTM 262875E 5333098N, Zone 18N;
UTM 709500E 5332020N, Zone 17N

Potential hazards:

- Steep and/or slippery slopes; loose rocks
- Stay off road shoulder and remain away from parked vehicles if possible; high-visibility vests required

The outcrop is approximately 3 km southwest of Stop 4-5 and approximately 5 km southwest of the Canadian Malartic pit (Photo 16A). Large staurolite poikiloblastic porphyroblasts (~1 cm) and garnet porphyroblasts (~1 mm) developed at the same time or slightly later than the main S_2 foliation (Photo 16B). The area is one of the best exposures of the mineral assemblage typical of the southward-trending Barrovian-type metamorphic gradient of the Pontiac Subprovince, with peak conditions of 550–600°C and 5–6 kilobars. Lutetium–hafnium (Lu/Hf) geochronology on garnet yielded a weighted average age of 2657.5±4.4 Ma (Piette-Lauzière et al. 2019). The formation of migmatites, S-type granite and pegmatitic granites of the Decelles Batholith, 10 km farther south, are related to this regional metamorphic event.

Approximately 200 m farther north, synsedimentary ultramafic–mafic metavolcanic flows (Photo 16D) and pillows (Photo 16C) are exposed on the northern side of the trail.

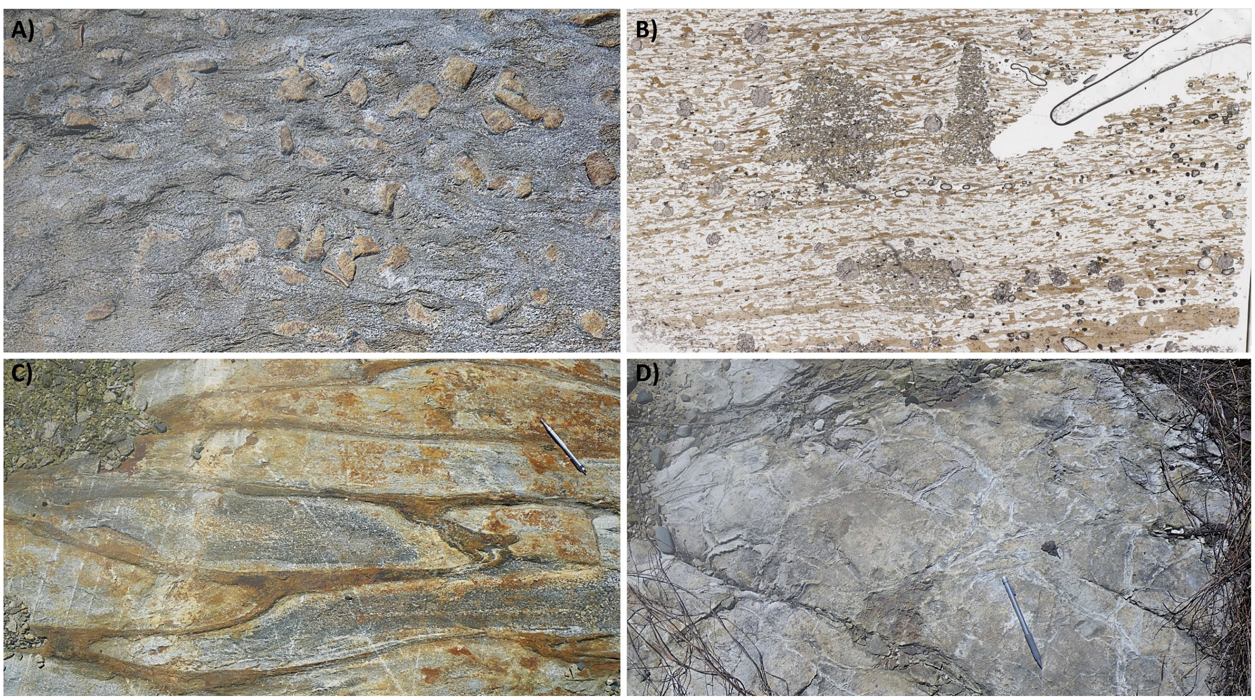

Photo 16. A) Field photograph of staurolite-garnet–bearing metagreywackes at Stop 4-6 (the outcrop shown in the image is ~0.3 m wide). **B)** Transmitted-light photomicrograph of a thin section of the rock from Stop 4-6 showing the staurolite and garnet in the rock, as well as the foliation and relict bedding. **C)** Stretched pillows exposed 200 m south of Stop 4-6 (the outcrop shown in the image is ~1 m wide; pen is 9 cm long). **D)** Ultramafic flow exposed 200 m south of Stop 4-6. The image shown is exposed approximately 200 m south of Stop 4-6 (the outcrop shown in the image is ~1 m wide; pen is 9 cm long).

End of road log.

Acknowledgments

Field trip leaders would like to thank Agnico Eagle Mines Limited (Macassa Mine and Canadian Malartic complex), Eldorado Gold Corporation (Sigma-Lamaque mines), Gold Candle Ltd. (Kerr-Addison Mine), Millstream Mines Limited (Potter Mine), and Newmont Corporation Porcupine operations (Hollinger Mine) for permitting access to their property and drill core during the preparation of this guidebook. Thanks to the Local Organizing Committee of the GAC–MAC–SGA Sudbury 2023 Meeting, in particular Bruno Lafrance, Riley Mulligan and Evan Hastie for reviewing this guidebook, and Cathryn Nadjiwon for her logistical support; and to Michael Easton and Monica Gaiswinkler Easton, Ontario Geological Survey, for additional reviews and editing, respectively. This is MERC–Metal Earth publication number MERC-ME 2023-24.

References

Ayer, J.A., Thurston, P.C., Bateman, R., Dubé, B., Gibson, H.L., Hamilton, M.A., Hathway, B., Hocker, S.M., Houlé, M.G., Hudak, G., Ispolatov, V.O., Lafrance, B., Lesher, C.M., MacDonald, P.J., Péloquin, A.S., Piercey, S.J., Reed, L.E. and Thompson, P.H. 2005. Overview of results from the Greenstone Architecture Project: Discover Abitibi Initiative; Ontario Geological Survey, Open File Report 6154, 146p.

Benn, K. 2004. Late Archaean Kenogamissi complex, Abitibi Subprovince, Ontario, Canada: Doming, folding and deformation-assisted melt remobilisation during syntectonic batholith emplacement; Transactions of the Royal Society of Edinburgh: Earth Sciences, v.95, no.1-2, p.297-307.

Berger, B.R. 2011. The Kidd–Munro episode – Volcanism and mineralization between 2720 and 2710 Ma; *in* Results from the Targeted Geoscience Initiative III Kidd–Munro Project, Ontario Geological Survey, Open File Report 6258, 77p.

Blacklock, N. 2015. Vein characterization using structural controls and petrographic analysis at the Cartier Zone in the Canadian Malartic Property, Québec; unpublished BSc thesis, Queen's University, Kingston, Ontario, 68p.

Bleeker, W. and van Breemen, O. 2011. New geochronological, stratigraphic, and structural observations on the Kidd–Munro assemblage and the terrane architecture of the south-central Abitibi greenstone belt, Superior craton, Canada; Ontario Geological Survey, Open File Report 6258, 35p.

Champagne, C. 2004. Volcanologie physique et géochimie des komatiites de Spinifex Ridge, Formation de la Motte-Vassan, Abitibi; unpublished MSc thesis, Université du Québec à Chicoutimi, Chicoutimi, Québec, 144p.

Coad, P.R. 1976. The Potter Mine; unpublished MSc thesis, University of Toronto, Toronto, Ontario, 239p.

Cooke, D.L. and Moorhouse, W.W. 1969. Timiskaming volcanism in the Kirkland Lake area, Ontario, Canada; Canadian Journal of Earth Sciences, v.6, p.117-132.

De Souza, S., Perrouty, S., Dubé, B., Mercier-Langevin, P., Linnen, R.L. and Olivo, G.R. 2020. Metallogeny of the Neoarchean Malartic gold camp, Québec, Canada; *in* Geology of the World's Major Gold Deposits and Provinces, Society of Economic Geologists, Special Publication 23, p.53-80.

Dubé, B. and Mercier-Langevin, P. 2020. Gold deposits of the Archean Abitibi greenstone belt, Canada; *in* Geology of the World's Major Gold Deposits and Provinces, Society of Economic Geologists, Special Publication 23, p.669-708.

Dubé, B., Mercier-Langevin, P., Ayer, J., Pilote, J.-L. and Monecke, T. 2020. Gold deposits of the world-class Timmins-Porcupine camp, Abitibi greenstone belt, Canada; *in* Geology of the World's Major Gold Deposits and Provinces, Society of Economic Geologists, Special Publication 23, p.53-80.

Ferguson, S.A., Buffam, B.S.W., Carter, O.F., Griffis, A.T., Holmes, T.C., Hurst, M.E., Jones, W.A., Lane, H.C. and Longley, C.S. 1968. Geology and ore deposits of Tisdale Township, District of Cochrane; Ontario Department of Mines, Geological Report 58, 177p.

Fisher, R.V. 1966. Rocks composed of volcanic fragments and their classification; Earth Science Reviews, v.1, p.287-298.

Fowler, A.D., Berger, B., Shore, M., Jones, M.I. and Ropchan, J. 2002. Supercooled rocks: Development and significance of varioles, spherulites, dendrites and spinifex in Archean volcanic rocks, Abitibi greenstone belt, Canada; Precambrian Research, v.115, p.311-328.

Frieman, B.M., Kuiper, Y.D., Kelly, N.M., Monecke, T. and Kylander-Clark, A. 2017. Constraints on the geodynamic evolution of the southern Superior Province: U-Pb LA-ICP-MS analysis of detrital zircon in successor basins of the Archean Abitibi and Pontiac subprovinces of Ontario and Quebec, Canada; Precambrian Research, v.292, p.398-416.

Gibson, H.L., Morton, R.L. and Hudak, G.J. 1999. Submarine volcanic processes, deposits, and environments favorable for the location of volcanic-associated massive sulfide deposits; *in* Volcanic-Associated Massive Sulfide Deposits: Processes and examples in modern and ancient settings, Society of Economic Geologists, Reviews in Economic Geology, v.8, p.13-52.

Gunning, H.C. and Ambrose, J.W. 1940. Malartic area, Québec; Geological Survey of Canada, Memoir 222, 142p.

Houlé, M.G., Lesher, C.M. and Préfontaine, S. 2017. Physical volcanology of komatiites and Ni-Cu-(PGE) deposits of the southern Abitibi greenstone belt; Chapter 4 *in* Archean Base and Precious Metal Deposits, Southern Abitibi Greenstone Belt, Canada, Society of Economic Geologists, Reviews in Economic Geology, v.19, p.103-132.

Hufford, G. 2015. Tectono-hydrothermal evolution of the Neoarchean Abitibi greenstone belt, Canada; unpublished MSc thesis, Colorado School of Mines, Golden, Colorado, 191p.

Hufford, G. and Monecke, T. 2019. Timiskaming sedimentary and intrusive rocks at Kinross Park, Kirkland Lake, Ontario; Geological Survey of Canada, Open File 8474, 6p. and 1 chart.

Katz, L.R., Kontak, D.J., Dubé, B. and McNicoll, V. 2017. The geology, petrology, and geochronology of the Archean Côté Gold large-tonnage, low-grade intrusion-related Au(-Cu) deposit, Swayze greenstone belt, Ontario, Canada; Canadian Journal of Earth Sciences, v.54, p.173-202.

Long, D.G.F. 2004. The tectonostratigraphic evolution of the Huronian basement and the subsequent basin fill: Geological constraints on impact models of the Sudbury event; Precambrian Research, v.129, p.203-223.

Lypaczewski, P., Rivard, B., Gaillard, N., Perrouty, S., Piette-Lauzière, N., Bérubé, C.L. and Linnen, R.L. 2019. Using hyperspectral imaging to vector towards mineralization at the Canadian Malartic gold deposit, Québec, Canada; Ore Geology Reviews, v.111, article 102945.

Monecke, T., Gibson, H.L. and Goutier, J. 2017. Volcanogenic massive sulfide deposits of the Noranda camp; Chapter 6 *in* Archean Base and Precious Metal Deposits, Southern Abitibi Greenstone Belt, Canada, Society of Economic Geologists, Reviews in Economic Geology, v.19, p.169-223.

Mueller, W., Donaldson, J.A. and Doucet, P. 1994. Volcanic and tectono-plutonic influences on sedimentation in the Archaean Kirkland Basin, Abitibi greenstone belt, Canada; Precambrian Research, v.68, p.201-230.

Neumayr, P., Hagemann, S.G. and Couture, J.F. 2000. Structural setting, textures, and timing of hydrothermal vein systems in the Val d'Or camp, Abitibi, Canada: Implications for the evolution of transcrustal, second- and third-order fault zones and gold mineralization; Canadian Journal of Earth Sciences, v.37, p.95-114.

Piette-Lauzière, N., Guilmette, C., Bouvier, A., Perrouty, S., Pilote, P., Gaillard, N., Lypaczewski, P., Linnen, R.L. and Olivo, G. 2019. The timing of prograde metamorphism in the Pontiac Subprovince, Superior craton: Implications for Archean geodynamics and gold mineralization; Precambrian Research, v.320, p.111-136.

Préfontaine, S. 2013. The definition, distribution and origin of hydrothermal alteration assemblages associated with the Potter volcanogenic massive sulfide deposit, Abitibi greenstone belt, Canada, unpublished MSc thesis, Laurentian University, Sudbury, Ontario, 78p.

Robert, F. 1994. Vein fields in gold districts, the example of Val-d'Or, southeastern Abitibi Subprovince, Québec; *in* Current Research, Geological Survey of Canada, Paper 1994-C, p.295-302.

Robert, F. and Brown, A.C. 1986. Archean gold-bearing quartz veins at the Sigma mine, Abitibi greenstone belt, Québec, Part I: Geologic relations and formation of the vein system; Economic Geology, v.81, p.578-592.

Rowland, S.K. and Walker, G.P.L. 1990. Pahoehoe and aa in Hawaii: Volumetric flow rate controls the lava structure; Bulletin of Volcanology, v.52, p.615-628.

Schmid, R. 1981. Descriptive nomenclature and classification of pyroclastic deposits and fragments: Recommendations of the IUGS Subcommission on the Systematics of Igneous Rocks; Geology, v.9, p.41-43.

Simoneau, J., Lind, P., Uludag, E., McKinley, S., Thelland, J., Murphy, M.K., Bouanani, M., Tran, V. and Sutherland, D. 2021. Technical report Lamaque project, Québec, prepared for Eldorado Gold Corporation by Eldorado Gold Corporation and Stantec Consulting Ltd.; NI 43-101 Technical Report, dated December 31, 2021, filed March 31, 2022 with SEDAR®, see SEDAR Home Page, 340p.

Smith, J.P., Spooner, E.T.C., Broughton, D.W. and Ploeger, F.R. 1993. Archean Au-Ag-(W) quartz vein/disseminated mineralisation within the Larder Lake – Cadillac break, Kerr Addison – Chesterville system, northeast Ontario, Canada, Ontario Geoscience Research Grant Program, Grant No. 364; Ontario Geological Survey, Open File Report 5831, 310p.

Thomson, J.E. 1943. Geology of the McGarry and McVittie townships, Larder Lake area; Ontario Department of Mines, Annual Report, 1941, v.50, pt.7, 99p.

Metric Conversion Table

Conversion from SI to Imperial			Conversion from Imperial to SI		
SI Unit	*Multiplied by*	*Gives*	*Imperial Unit*	*Multiplied by*	*Gives*
		LENGTH			
1 mm	0.039 37	inches	1 inch	**25.4**	mm
1 cm	0.393 70	inches	1 inch	**2.54**	cm
1 m	3.280 84	feet	1 foot	**0.304 8**	m
1 m	0.049 709	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	**1.609 344**	km
		AREA			
1 cm^2	0.155 0	square inches	1 square inch	**6.451 6**	cm^2
1 m^2	10.763 9	square feet	1 square foot	**0.092 903 04**	m^2
1 km^2	0.386 10	square miles	1 square mile	2.589 988	km^2
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
		VOLUME			
1 cm^3	0.061 023	cubic inches	1 cubic inch	**16.387 064**	cm^3
1 m^3	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m^3
1 m^3	1.307 951	cubic yards	1 cubic yard	0.764 554 86	m^3
		CAPACITY			
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	**4.546 090**	L
		MASS			
1 g	0.035 273 962	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 747	ounces (troy)	1 ounce (troy)	**31.103 476 8**	g
1 kg	2.204 622 6	pounds (avdp)	1 pound (avdp)	**0.453 592 37**	kg
1 kg	0.001 102 3	tons (short)	1 ton(short)	**907.184 74**	kg
1 t	1.102 311 3	tons (short)	1 ton (short)	**0.907 184 74**	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	**1016.046 908 8**	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	**1.016 046 9**	t
		CONCENTRATION			
1 g/t	0.029 166 6	ounce (troy) / ton (short)	1 ounce (troy) / ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights / ton (short)	1 pennyweight / ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

	Multiplied by	
1 ounce (troy) per ton (short)	31.103 477	grams per ton (short)
1 gram per ton (short)	0.032 151	ounces (troy) per ton (short)
1 ounce (troy) per ton (short)	20.0	pennyweights per ton (short)
1 pennyweight per ton (short)	0.05	ounces (troy) per ton (short)

*Note: Conversion factors in **bold** type are exact. The conversion factors have been taken from or have been derived from factors given in the* Metric Practice Guide for the Canadian Mining and Metallurgical Industries*, published by the Mining Association of Canada in co-operation with the Coal Association of Canada.*

ISSN 0826-9580 (print)
ISBN 978-1-4868-7219-0 (print)

ISSN 1916-6117 (online)
ISBN 978-1-4868-7220-6 (PDF)