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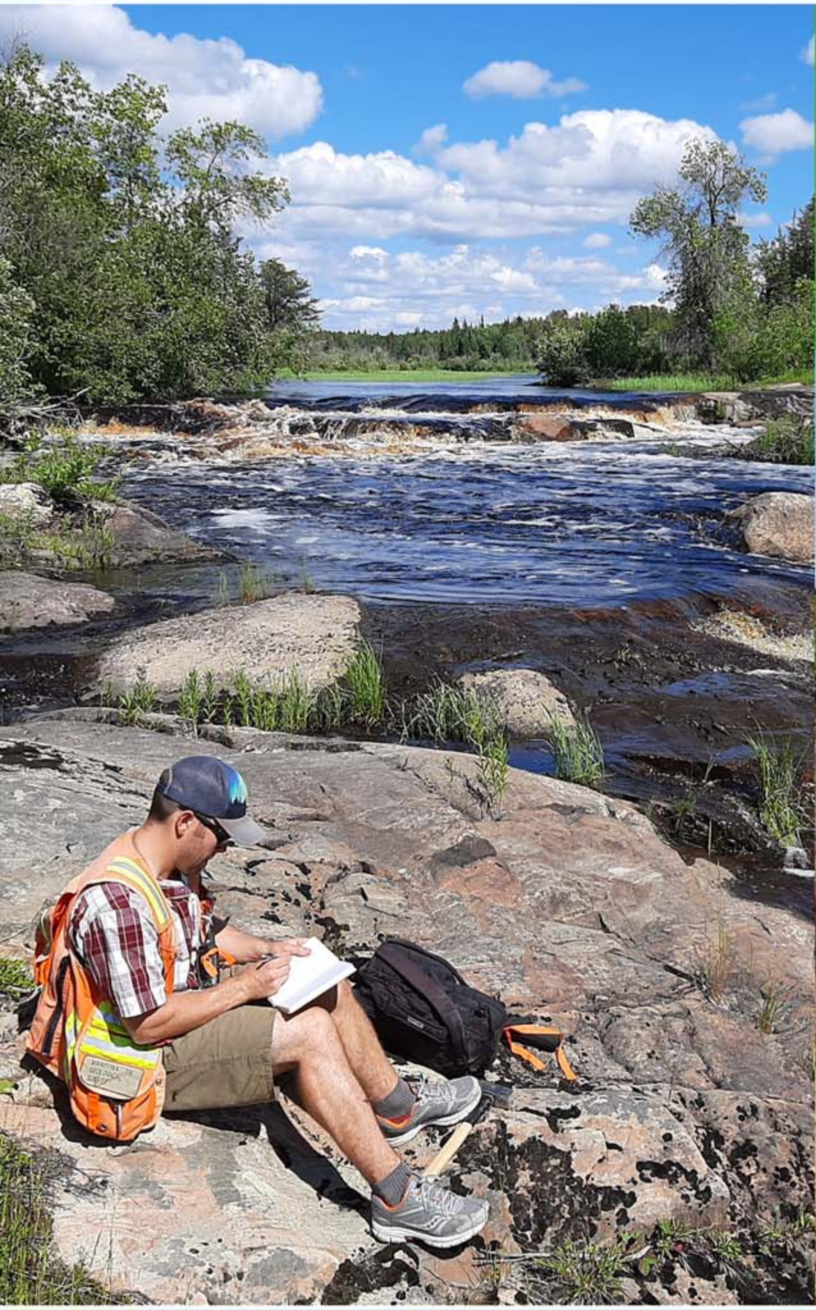

REPORT OF ACTIVITIES 2020

Manitoba Geological Survey

Manitoba

REPORT OF ACTIVITIES
2020

Manitoba Agriculture and Resource Development
Manitoba Geological Survey

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Front cover photos:
Left: Geological mapping of riverside bedrock exposures near East Side Road (GS2020-1, this volume).
Right: Large gravel pit north of Gillam exposes two different tills overlying thick interglacial sands and gravels.

REPORT OF ACTIVITIES 2020

Minister's Message

As Minister of Agriculture and Resource Development, I am pleased to introduce the Manitoba Geological Survey's (MGS) annual *Report of Activities*. The 2020 edition features eight professional geoscience reports and provides an update on key projects and activities from this year. Each report contributes to the overall delivery of a knowledge base that is fundamental to the future as we move forward to rebuild and draw investment, exploration and development to our province's valuable minerals sector.

This year's report represents a special achievement in the face of many challenges since March 2020 due to the COVID-19 pandemic.

The department's geoscience team is committed to ensuring the industry is supported during these most unprecedented times. A rapid response approach by Survey staff included developing new internal protocols alongside long-term health and safety measures, and set the stage for a number of field projects to take place this summer on short notice, conducted in accordance with public health orders.

The Survey also produced a record number of reports and data releases throughout the year.

In addition to this year's report, I recommend visiting the MGS website at Manitoba.ca/minerals where you can review the *Manitoba Mining, Exploration and Geoscience 2020–2021* brochure along with comprehensive databases, reports, maps and digital products.

As we work towards safely restarting the economy, the minerals sector remains vital to Manitoba's growth. The MGS continues to play an important role in building a legacy of knowledge while working with industry, Indigenous communities, educators, associations and others.

Manitoba is also actively participating in the *Canadian Minerals and Metals Plan*, supporting the vision, principles and strategic directions that governments, industry and stakeholders can pursue to drive industry competitiveness and long-term success.

Manitoba's resources are as great and diverse as our citizens. The sector has a long history of resilience, and there are always new opportunities to take hold of as we stay the course. We are in this together and stand by our Survey's commitment that there is *always* more to explore!

Original signed by

Honourable Blaine Pedersen

Manitoba Agriculture and Resource Development

Rapport d'activités 2020

Message du ministre

En qualité de ministre de l'Agriculture et du Développement des ressources, j'ai le plaisir de présenter le *Rapport d'activités* annuel de la Direction des services géologiques du Manitoba (la Direction). Le Rapport 2020 présente huit rapports géoscientifiques préparés par des spécialistes et fait le point sur les activités et projets essentiels de l'année. Chaque rapport contribue globalement à la construction d'une base de connaissances essentielle pour l'avenir, à mesure que nous avançons pour rebâtir et stimuler l'investissement, l'exploration et le développement dans le précieux secteur des minéraux de notre province.

Le rapport de cette année représente une réalisation particulière compte tenu des nombreux défis soulevés par la pandémie de COVID-19 depuis mars 2020.

L'équipe géoscientifique du ministère est déterminée à veiller au soutien de l'industrie en cette période sans précédent. L'approche adoptée par le personnel de la Direction, qui était axée sur une intervention rapide, comprenait l'élaboration de nouveaux protocoles internes et de mesures d'hygiène et de sécurité à long terme. De plus, elle jetait les bases de divers projets exécutés sur le terrain dans un délai très court cet été, conformément aux ordres de santé publique.

Tout au long de l'année, la Direction a également produit un nombre record de rapports et de publications de données.

Outre le rapport de cette année, je recommande la visite du site Web de la Direction (Manitoba.ca/minerals), où vous pourrez consulter (en anglais seulement) la brochure *Manitoba Mining, Exploration and Geoscience 2020-2021* ainsi qu'un ensemble complet de bases de données, de rapports, de cartes et de produits numériques.

Alors que nous œuvrons au redémarrage de l'économie de manière sécuritaire, le secteur des minéraux demeure vital pour la croissance du Manitoba. La Direction continue de jouer un rôle important en contribuant à amasser un héritage de connaissances tout en travaillant avec l'industrie, les communautés autochtones, les éducatrices et éducateurs, les associations et d'autres parties.

De plus, le Manitoba participe activement au *Plan canadien pour les minéraux et les métaux*, en soutenant la vision, les principes et les orientations stratégiques que les gouvernements, l'industrie et les parties prenantes peuvent poursuivre afin de favoriser la compétitivité de l'industrie et son succès à long terme.

Les ressources du Manitoba sont aussi précieuses et diverses que notre population. Le secteur a une longue tradition de résilience et de nouvelles possibilités demeureront à sa portée tandis que nous gardons le cap. Nous sommes solidaires et la Direction demeure fidèle à son engagement : il y a *toujours* plus à explorer!

Origional signé par

Blaine Pedersen

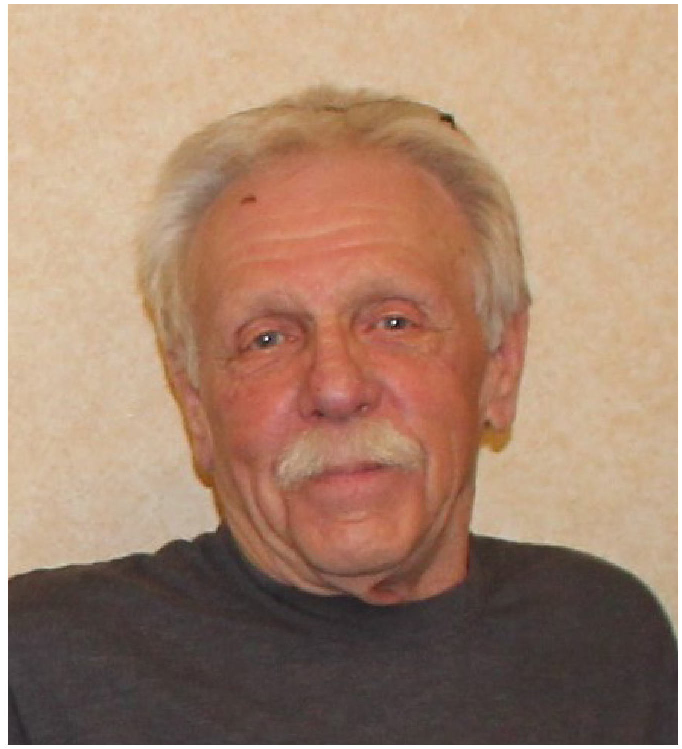
Agriculture et Développement des ressources

In Memoriam: Douglas Berk

by M.P.B. Nicolas

After a difficult battle with cancer, Douglas Berk passed away in Winnipeg on November 18, 2019 at the age of 68. Doug was born in Russell, Manitoba on August 16, 1951. At a young age he moved to Winnipeg with his family and put down roots in St. Vital, where he would eventually raise his own family. He met his lifelong partner and wife Phyllis at work. Doug and Phyllis were married 35 years and had two sons, Daniel and Michael, whom Doug adored. Doug loved the outdoors, spending every summer at Big Whiteshell campground in southeastern Manitoba where he made many close friends and knew all the secret fishing spots. Doug enjoyed curling in his younger years and was an avid fisherman his whole life. Doug had a personality that was larger than life; he was friendly and could talk to anyone, making them feel at ease with his jokes, teasing and laughter.

Doug worked his entire career for the Manitoba Geological Survey (MGS); a career that lasted for 32 years from 1975 to 2007. He started as a Lab Technician and eventually rose to the position of Core Lab Manager. For many years, Doug spent summers on the diamond drill, cutting core all over Manitoba. He greatly enjoyed fieldwork which gave him the opportunity to travel all over the province, experiencing everything from Manitoba's breathtaking wilderness and lakes to the majestic splendor of polar bears in Churchill. During Doug's long career at the MGS core lab, he became a valuable resource and core "historian". Given the hundreds of cores he drilled and samples he saw, he could recall impressive details about many of them. He could often provide anecdotes, stories and weather reports about the day a core was drilled; recalling a particular event of the day or of that drilling season, or the student that was helping him that year. Underneath his tough exterior, he had a great fondness for everyone he worked with and he cared about them deeply; they were like family. Doug was always quick to volunteer when something needed to be done, and was a key contributor towards the success of both the annual Manitoba Mining and Minerals Convention and Provincial Mining Week events.



Always interested in geology and believing in the untapped mineral potential of Manitoba, Doug took on the role of prospector with his company White Cap Exploration after his retirement. He enjoyed the thrill of the mineral hunt and tackled his property with excitement and passion. This excitement, paired with his ability to connect with people and communities, was paid back in lasting friendships, respect and trust from all those who had the pleasure of working with him.

I had the benefit of working with Doug when I was a university student and for years as a colleague after joining the Government of Manitoba. He always went above and beyond to help me, or anyone who asked for it. He always made me feel at ease, teasing me frequently; his laughter echoing in the core viewing room. To my horror, he would often joke that he would, one day, put a spider in my core box. I never did come across a spider, but I know that if I ever do come across one, I'll know who put it there.

In Memoriam: Glenn Conley

by M.P.B. Nicolas

Glenn Conley passed away peacefully from cancer on September 21, 2020 in Winnipeg at the age of 74. Glenn grew up in Winnipeg's North End where he attended King Edward School and Sisler High School. He attended the University of Winnipeg, followed by the University of Manitoba where he received his M.Sc. in Geology in 1986. Glenn was a man of big stature, towering over most of us. He was also quiet and reserved; a gentle giant. He loved woodworking, often talking about how, in his retirement, he planned to make furniture that he could sit in comfortably. Glenn also enjoyed cooking, camping, and reading. He enjoyed visiting Fort Whyte Alive where he found stillness and harmony.

Glenn had a passion for computers. He excelled at programming and database structure, pioneering several geological databases in his 28-year career at the Manitoba Geological Survey (MGS). Glenn started with the MGS in 1987 as the first (and, to this day, only) Database Geologist. Armed with a strong geological background and the endless possibilities that the new world of computer databases provided, he dove right in; when he started, Glenn was the only person to have a computer to himself. His first big project was to create early versions of what are now the Manitoba Oil and Gas Well Information System and the Manitoba Stratigraphic Database. Working with fellow MGS colleague Ruth Bezys, Glenn converted and entered paper-based data from MGS files into a newly created digital database, which, at the time, was an enormous feat. Glenn's tireless effort and patience creating these databases truly set the groundwork for Manitoba's digital future.

I had the benefit of working with Glenn as a student and as a colleague. To a young student he was intimidating, if only in stature, as he was always helpful and patient. When I worked with him, most closely on the Williston Basin Targeted Geoscience Initiative 2 project, I really got a sense and appreciation for how much he knew about databases. Glenn understood a database's forward-looking applications and, most importantly, its limitations. After his retirement, I saw Glenn at an MGS event. He expressed the excitement he felt that the wood he had ordered for his furniture was due to arrive any day. I hope he was able to make his 'Glenn-sized' chair and enjoy it.

Foreword

On behalf of the Manitoba Geological Survey (MGS), it is my privilege to present the *Report of Activities 2020*—the annual peer-reviewed volume of geoscience projects results by the MGS.

On October 24, 2019, the Resource Development Division merged with the Department of Agriculture and the Water Stewardship and Biodiversity Division from Sustainable Development to become the Department of Agriculture and Resource Development. This amalgamation brings agriculture, forestry and peatlands, wildlife and fisheries, water science and Crown lands together with mining, oil and gas and the Geological Survey. The goal is to have all the land uses under one ministry, which will help streamline processes and create the foundation for an integrated planning approach to the land, its resources and development thereof.

After over a decade of declining budgets, the MGS saw a slight increase in its operating budget for this fiscal year. This allowed the MGS to plan a more robust field season than in recent years. Then the COVID-19 pandemic spread to Canada, with a historical shutdown and isolation period that has affected everyone in every sector and walk of life. The resource industry was hit hard, with exploration programs being halted and mining operations running on minimal staff or shut down temporarily. In March, the MGS moved to a dominantly "work from home" model, with only a skeleton staff in the office at any time. The field program immediately was in danger of being completely cancelled. As the field season approached, the geologists developed multiple versions of field programs while considering a strict set of health protocols and ensuring there would be expediting support and enough leeway time to prepare.

Despite the challenges brought on by the pandemic, six field projects were successfully completed this year. This *Report of Activities* annual volume and accompanying preliminary map and data repositories present the findings of new and advanced projects, and includes important contributions to Manitoba's geological knowledge infrastructure. This volume includes two critical mineral projects: (1) expanded mapping from last year's field program in Russell Lake with new graphite occurrences and insights into their importance (Martins and Couëslan, GS2020-5, this volume); and (2) investigations into Zr- and light rare-earth element (REE)-enriched rocks on the Huzyk Creek property and implications for Zr, Nb, U and REE potential in the Kisseynew domain (Couëslan, GS2020-3, this volume). Surficial (Gauthier and Hodder, GS2020-6, this volume) and bedrock (Rinne, GS2020-1, this volume) mapping along and near the newly extended East Side Road, located along the eastern shore of Lake Winnipeg, reported many new exposures, good field access and identified potential for multiple deposit types, including possible granite dimension stone quarry sites near Bloodvein First Nation. Ongoing studies in the exposed and sub-Phanerozoic portions of the Flin Flon belt continued southeast of Wekusko Lake, in the areas of the Mitishto and Hargrave rivers, where the Watt River volcanicogenic massive-sulphide (VMS) deposit is located; new insights suggest great potential for VMS as well as magmatic Ni-Cu deposits to occur in the area (Reid, GS2020-4, this volume). Surficial geological mapping and till sampling, including kimberlite-indicator minerals samples, in northeastern Manitoba will inform drift exploration in the Fox River belt, with potential to host Ni, Cu and platinum-group element deposits, and provide information to better assess the regional-scale diamond potential of the area (Gauthier and Hodder, GS2020-7, his volume).

The MGS, while engaged in field projects, is also hard at work on internal initiatives to improve service delivery and products. Two examples of such initiatives include till-matrix geochemistry compilations and updating the Mineral Deposits Database (MDD). The former consists of the compilation of MGS data from 12 464 till samples collected from 53 different projects (Gauthier, this volume, GS2020-8) since the 1980s. The data is represented in a series of publications that will inform exploration projects for years to come. The MDD, which consists of a compilation of reported mineral occurrences throughout Manitoba dating back decades, is being updated and modernized to include previously excluded mineral occurrences, including critical minerals and rare metals. This year, the MDD update was focused on the Island Lake region. This work resulted in adding approximately 100 new occurrences in the database, and updating 150 existing ones (Rinne, GS2020-2, this volume). This is a multi-year initiative of a client-focused product that is frequently used by the exploration community.

With a reduction in field programming in recent years and more geologists being in the office, this has allowed the MGS to focus on preparing data and reports for publication and public release. Putting fingers to keyboard, the MGS was able to complete larger, more time-consuming geoscience reports (Open Files, Geoscientific Reports, Geoscientific Papers), as well as compile old datasets from previous field programs never before released to the public. The result is a record year in publications and new releases. Since October 1, 2019, the MGS had a total of 81 releases, including new data releases (Data Repository Items), various reports and digital re-releases (old reports previously only available in hard copy). An impressive accomplishment given that the staff count of the MGS is the smallest it has been since the 1960s. I encourage everyone to take the time to review the long list of information now available digitally, and to stay informed by bookmarking the new releases webpage at https://www.manitoba.ca/iem/info/libmin/newpubs.html to keep on top of the great work the MGS is doing. You can also subscribe to our new releases mailing list (minesinfo@gov.mb.ca) and have our new publications notices sent directly to your inbox.

One of the key support services the MGS benefits from, and could not function without, are the Geoscience Data Management (GDM) section (Greg Keller, Acting Section Head) and the Regulatory Geoscience section (Pamela Fulton-Regula, Acting Chief Geologist). The GDM section provides

GIS and digital services and is often behind the scenes on all the products the MGS produces. This includes setting up our digital needs for field projects and producing our preliminary maps, document and map scanning, and database creation and upkeep. This hard-working and skilled group was key to the creation of the long anticipated new 250k scale common map legend which has now transitioned into updating the Manitoba 1:1M map legend, and the compilation and digitization of historical aggregate reports and maps. The Regulatory Geoscience section includes crucial work such as the review of assessment reports and assignment of work credits, Phanerozoic stratigraphic tops picking and oil field coding, field expediting services, and rock preparation and core library management.

Over the last year, the MGS successfully hired a GIS geologist, Hakeem Adediran, to be mentored and trained by the senior GIS Geologist, Len Chackowsky. This succession plan will ensure the wealth of information, expertise and corporate knowledge Len has will be transferred to a new generation of geoscientists, helping to maintain the legacy of the MGS.

The recent passing of two fellow MGS retirees Doug Berk (Core Lab Manager) and Glenn Conley (Database Geologist) have saddened us, while reminding us to chase our dreams and enjoy every day as it comes. My condolences go out to the families of these two exceptional individuals.

The dedicated and diligent work of the MGS Chief Geologist (Christian Böhm), all the project geologists, GIS technicians, and lab technicians went into the production of the *Report of Activities 2020*. I would like to acknowledge Bob Davie and his hard-working team from RnD Technical who carefully performed technical editing, and Craig Steffano who managed report production and publication layout. I would like to thank everyone at the MGS for their valuable contributions, dedication, and enthusiasm to the projects and initiatives tackled over the last year. The MGS did not let COVID-19 hold them back, and they excelled despite the challenges it presented.

Michelle P.B. Nicolas, P.Geo., FGC

Acting Director, Manitoba Geological Survey

Avant-propos

J'ai l'honneur de présenter au nom de la Direction des services géologiques du Manitoba (la Direction) le *Rapport d'activités 2020*, un recueil annuel examiné par les pairs compilant les résultats de projets géoscientifiques exécutés par la Direction.

Le 24 octobre 2019, la Division du développement des ressources a fusionné avec le ministère de l'Agriculture et la Division de la gestion des ressources hydriques et de la biodiversité de Développement durable pour devenir le ministère de l'Agriculture et du Développement des ressources. Sont ainsi regroupés l'agriculture, les forêts et tourbières, la faune et la pêche, les sciences de l'eau et les terres domaniales avec le développement minier, le pétrole et le gaz ainsi que les services géologiques. L'objectif est que toutes les formes possibles d'aménagement du territoire relèvent d'un même ministère, ce qui aidera à rationaliser les processus et à jeter les bases d'une approche intégrée de planification de l'aménagement du territoire, de ses ressources et de leur développement.

Après plus d'une décennie de compression budgétaire, la Direction a bénéficié d'une légère augmentation de son budget de fonctionnement pour cet exercice. Cela a permis à la Direction de planifier une saison sur le terrain plus active que ces dernières années. Par la suite, la pandémie de COVID 19 s'est propagée au Canada, avec une période sans précédent d'arrêt et de confinement qui a touché chacun et chacune d'entre nous, de tous les horizons et dans les tous secteurs. L'industrie des ressources a été durement atteinte, avec la suspension des programmes d'exploration et l'arrêt temporaire des activités minières ou leur exécution avec un personnel réduit au minimum. En mars, la Direction est passée à un modèle de fonctionnement principalement axé sur le télétravail, ne conservant à tout moment qu'un minimum de personnel dans les bureaux. Le programme sur le terrain a tout de suite été menacé d'une annulation totale. À mesure que la saison sur le terrain approchait, les géologues ont mis au point plusieurs versions des programmes sur le terrain tout en étudiant un ensemble rigoureux de protocoles sanitaires et en veillant à la mise en place de soutien rapide et à ce que le temps de préparation imparti soit suffisant.

Malgré les défis soulevés par la pandémie, six projets sur le terrain ont été exécutés avec succès cette année. Le recueil annuel du présent *Rapport d'activités* et les dépôts de données et de cartes préliminaires qui l'accompagnent présentent les résultats de projets (certains qui viennent d'être lancés et d'autres, plus avancés) et renferment des contributions importantes à l'infrastructure de connaissances géologiques du Manitoba. Le présent recueil inclut deux projets de la plus haute importance en matière d'exploitation minière : (1) la cartographie élargie issue du programme exécuté l'an dernier sur le terrain dans la zone du lac Russell, avec de nouveaux affleurements de graphite et des renseignements sur leur importance (Martins et Couëslan, GS2020-5, présent recueil); (2) des études sur les roches enrichies de zirconium (Zr) et d'éléments des terres rares (ETR) légères sur la propriété du ruisseau Huzyk et leurs implications en ce qui concerne la présence possible de Zr, de niobium (Nb), d'uranium (U) et d'ETR dans le domaine de Kisseynew (Couëslan, GS2020-3, présent recueil). La cartographie des matériaux superficiels (Gauthier et Hodder, GS2020-6, présent recueil) et du substratum (Rinne, GS2020-1, présent recueil) le long et à proximité de la route située du côté est du lac Winnipeg (qui vient d'être prolongée) a mis en évidence de nombreux nouveaux affleurements, un bon accès sur le terrain et des possibilités de plusieurs types de dépôts, notamment des sites de carrière de granite pour l'exploitation de pierres de taille près de la Première nation de Bloodvein. Les études en cours dans les parties exposées et subphanérozoïques de la ceinture de Flin Flon se sont poursuivies au sud-est du lac Wekusko, dans les bassins des rivières Mitishto et Hargrave, où est situé le gisement de sulfures massifs volcanogènes (SMV) de la rivière Watt; de nouveaux renseignements semblent indiquer un potentiel élevé de dépôts de SMV et de Ni-Cu magmatique dans cette zone (Reid, GS2020-4, présent recueil). Au nord-est du Manitoba, la cartographie géologique de surface et l'échantillonnage de tills, y compris des échantillons de minéraux indicateurs de kimberlite, orienteront l'exploration glacio-sédimentaire dans la ceinture de la rivière Fox, avec la présence possible de gisements d'éléments du groupe nickel, cuivre et platine, et procureront de l'information permettant de mieux évaluer le potentiel diamantaire de la zone à l'échelon régional (Gauthier et Hodder, GS2020-7, présent recueil).

La Direction, tout en exécutant des projets sur le terrain, travaille également d'arrache-pied à des initiatives internes visant à améliorer la prestation de services et les produits. Deux exemples de telles initiatives sont les compilations géochimiques de la matrice du till et l'actualisation de la base de données MDD sur les gisements minéraux. Les compilations susmentionnées rassemblent des données de la Direction des services géologiques issues de 12 464 échantillons de till collectés dans 53 projets différents (Gauthier, présent recueil, GS2020-8) depuis les années 1980. Les données sont présentées dans une série de publications qui alimentera les projets d'exploration au cours des années à venir. La base de données MDD, qui compile des venues minérales signalées dans tout le Manitoba depuis des décennies, fait actuellement l'objet d'une mise à jour et d'une actualisation qui inclura des gisements de minéraux jusque-là exclus, en particulier des métaux rares et des minéraux essentiels. Cette année, la mise à jour de MDD était centrée sur la région du lac Island. Ce travail s'est traduit par l'ajout à la base de données d'une centaine de nouveaux gisements et la mise à jour de 150 gisements existants (Rinne, GS2020-2, présent recueil). Il s'agit d'une initiative pluriannuelle de produit axé sur le client fréquemment utilisé par les acteurs de l'exploration.

La réduction des activités sur le terrain ces dernières années et l'accroissement du nombre de géologues travaillant depuis les bureaux ont permis à la Direction de se centrer sur la préparation de données et de rapports en vue de leur publication et de leur diffusion publique. Ainsi, le personnel de la Direction, qui passe plus de temps devant ses ordinateurs, a pu élaborer des rapports géoscientifiques plus détaillés et plus chronophages (dans les collections « Open Files », « Geoscientific Reports », « Geoscientific Papers ») et compiler d'anciens ensembles de données collectés lors de programmes antérieurs sur le terrain et qui n'avaient jamais été rendus publics. De fait, cet exercice a été marqué par un nombre record de documents et de nouvelles publications. Depuis le 1er octobre 2019, la Direction a réalisé un total de 81 publications, notamment de nouvelles données (dans la collection « Data Repository Items »), de rapports divers et, toujours sous forme numérique, de données existantes qui n'étaient jusque-là disponibles qu'en version imprimée. Il s'agit là de réalisations remarquables si l'on sait que l'effectif de la Direction n'a jamais été aussi réduit depuis les années 1960. Je vous encourage tous à prendre le temps de parcourir la longue liste de publications disponibles à ce jour par voie numérique et à rester informés sur les travaux exceptionnels réalisés par la Direction en ajoutant à vos favoris la page Web consacrée aux nouvelles publications (https://www.manitoba.ca/iem/info/libmin/newpubs.html, en anglais seulement). Vous pouvez aussi vous abonner à la liste d'envoi liée à nos nouvelles publications (minesinfo@gov.mb.ca) pour recevoir directement par courriel nos avis concernant les dernières publications.

Deux des principaux services de soutien dont bénéficie la Direction et sans lesquels elle ne pourrait pas fonctionner sont la Section de la gestion des données géoscientifiques (Greg Keller, gestionnaire par intérim) et la Section des services de soutien géoscientifique lié à la réglementation (Pamela Fulton-Regula, géologue en chef par intérim). La Section de la gestion des données géoscientifiques fournit des services numériques et d'information géographique (SIG). Elle contribue souvent en coulisses à l'élaboration de tous les produits de la Direction. Ses activités comprennent l'établissement de nos besoins numériques pour les projets sur le terrain et la production de nos cartes préliminaires, la numérisation de documents et de cartes ainsi que la création et la mise à niveau des bases de données. Cette équipe dévouée et compétente a joué un rôle essentiel dans la création de la nouvelle légende de carte commune à l'échelle 1:250 000e, que l'on attendait depuis longtemps et dont on se sert actuellement dans la transition pour la mise à niveau de la légende à l'échelle 1:1 000 000e du Manitoba, ainsi que dans la compilation et la numérisation de cartes et de rapports sommaires historiques. La Section des services de soutien géoscientifique lié à la réglementation est chargée de certaines activités cruciales comme l'examen des rapports d'évaluation et l'octroi du report des dépenses engagées pour certains travaux, la détermination du point le plus haut de l'horizon stratigraphique phanérozoïque et le codage des champs de pétrole, les services d'expédition sur le terrain ainsi que la préparation des roches et la gestion de la bibliothèque de base.

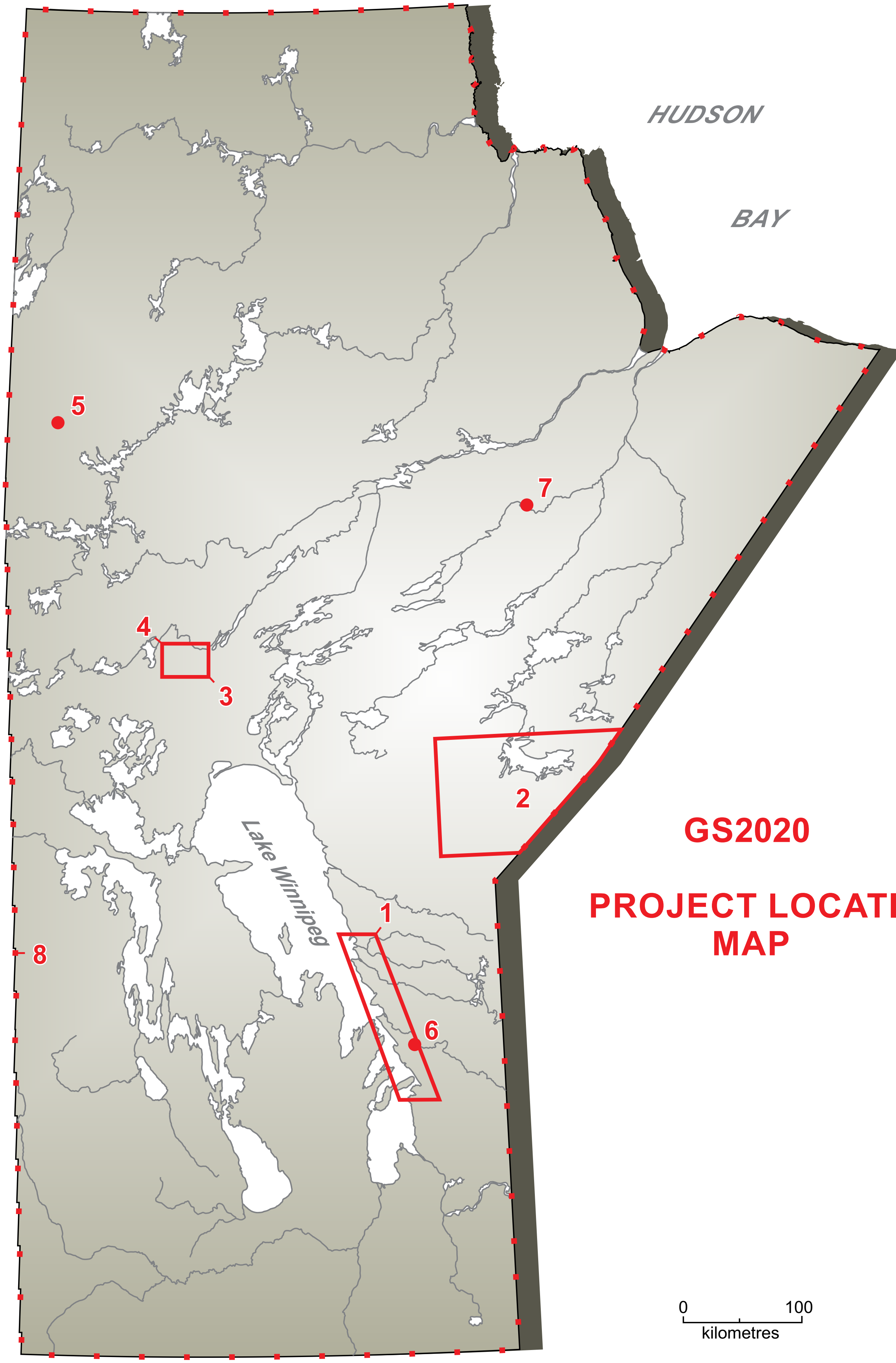
Au cours de l'exercice écoulé, la Direction a recruté avec succès un géologue SIG, Hakeem Adediran, dont le mentor et le formateur seront le géologue SIG principal, Len Chackowsky. Cette mesure de planification de la relève garantira que la mine de renseignements, de compétences et de connaissances organisationnelles détenue par Len Chackowsky sera transmise à une nouvelle génération de géoscientifiques, aidant ainsi à préserver notre héritage au sein de la Direction.

Les récents décès de deux collègues retraités de la Direction, Doug Berk (gestionnaire d'activités de laboratoire de base) et Glenn Conley (géologue responsable de bases de données), nous ont attristés, tout en nous rappelant à quel point il est important de poursuivre nos rêves et d'apprécier chaque jour que nous vivons. Nous offrons nos condoléances aux familles de ces deux personnes exceptionnelles.

Le *Rapport d'activités 2020* est le fruit du travail dévoué et méticuleux du géologue en chef de la Direction (Christian Böhm) ainsi que de l'ensemble des géologues de projet, des techniciens SIG et des techniciens de laboratoire. Je tiens à saluer Bob Davie et son équipe à RnD Technical, qui ont pris soin de la révision technique, et Craig Steffano, qui a géré la production du rapport et la mise en pages de la publication. Je souhaite remercier tous les membres de la Direction de leurs précieuses contributions ainsi que du dévouement et du dynamisme dont ils font preuve dans le cadre des projets et des initiatives de l'année écoulée. La Direction n'a pas laissé la COVID-19 la freiner, et notre équipe a excellé malgré les défis liés à la pandémie.

La directrice par intérim des Services géologiques,

Michelle P.B. Nicolas, P.Geo., FGC



GS2020

PROJECT LOCATION MAP

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PUBLICATIONS

GS2020-1

Results of reconnaissance bedrock mapping along East Side Road, southeastern Manitoba (parts of NTS 62P1, 7, 8, 10, 15, 63A2, 7)

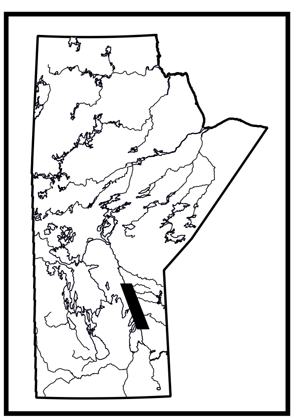
by M.L. Rinne

In Brief:

- Reconnaissance bedrock mapping was carried out along the new ~160 km route near the southeast shore of Lake Winnipeg
- Gneissic granitoid units were encountered along with gabbro and granitic pegmatite dikes
- Sites near Bloodvein First Nation may be suitable for dimension stone quarrying

Citation:

Rinne, M.L. 2020: Results of reconnaissance bedrock mapping along East Side Road, southeastern Manitoba (parts of NTS 62P1, 7, 8, 10, 15, 63A2, 7); *in* Report of Activities 2020, Manitoba Agriculture and Resource Development, Manitoba Geological Survey, p. 1–8.



Summary

The recently constructed East Side Road was selected for new geological mapping by the Manitoba Geological Survey (MGS). Reconnaissance bedrock mapping was carried out by truck and short inland traverses along the approximately 160 km route near the southeastern shore of Lake Winnipeg. Dominantly gneissic units of tonalite, quartz diorite, granite to granodiorite, megacrystic granite and porphyritic granite of the Berens River domain were encountered, along with minor gabbro dikes and widespread granitic pegmatite dikes. Most of the outcrops along East Side Road display a well-developed gneissosity followed in places by late shears, faults and fractures. Preliminary results indicate that some sites near Bloodvein First Nation could be suitable for dimension stone (e.g., polished granite slab) quarrying.

Introduction

In 2020, bedrock exposures including new roadcuts and quarry walls were examined along East Side Road, an all-season road that connects the First Nation communities of Berens River and Bloodvein to Provincial Road 304 near Hollow Water First Nation (Figure GS2020-1-1a). Quaternary investigations, including ice-flow mapping and till sampling, were carried out along the same route; the preliminary results of that work are described in Gauthier and Hodder (2020). In addition to the results reported here, an Open File release of geochemical and geochronological data from this project is planned following receipt of results from analyses of the 2020 field samples.

The southernmost 40 km of East Side Road (previously Rice River Road) has been mapped and described by several workers, particularly in areas nearest Provincial Road 304; much of that work was compiled by Bailes et al. (2003). The remaining 120 km of road from Loon Bay to Berens River is new, extending through a region that lacks geochronological data and has seen little mapping, mostly limited to shoreline surveys and helicopter-supported regional work by the Geological Survey of Canada (Ermanovics, 1970a, b). Current understanding of the geology in the study area relies heavily on interpretations from 1970 and earlier, despite complications such as inconsistent legends and unit names that do not correspond to the nomenclature (Streckeisen, 1974) currently employed by the MGS.

Regional geology

Rocks mapped along East Side Road are located in the Berens River domain, a large region dominated by Neoarchean granitoid plutons that occupies most of the eastern shoreline of Lake Winnipeg and extends into Ontario across the western part of the Superior province. In Manitoba, the Berens River domain is bounded to the north by an unnamed regional shear zone through the Cobham River–Gorman Lake greenstone belt and to the south by the Wanipigow shear zone (Figure GS2020-1-1a). Supracrustal units are rare in the Berens River domain; notable examples are located in the Horseshoe Lake area in Manitoba (northeast of the map area shown in Figure GS2020-1-1a), and around Oooowee Sahkaheekahn/McInnes Lake (formerly McInnes Lake), Hornby Lake and Cherrington Lake in Ontario (Stone, 1998). Ultramafic intrusions have also been documented at several locations within granitoid units near the Wanipigow shear zone, including the English Lake intrusive complex (ELC in Figure GS2020-1-1a).

The Berens River domain forms the core of the North Caribou superterrane, which extends from the Uchi domain in the south to the Oxford–Stull domain in the north. The North Caribou superterrane represents a crustal block that was assembled relatively early during the amalgamation of the Superior province; its extent can be defined by ca. 3.0 Ga mantle-extraction ages (Hollings et al., 1999; Percival et al., 2006). Later magmatism and deformation have substantially

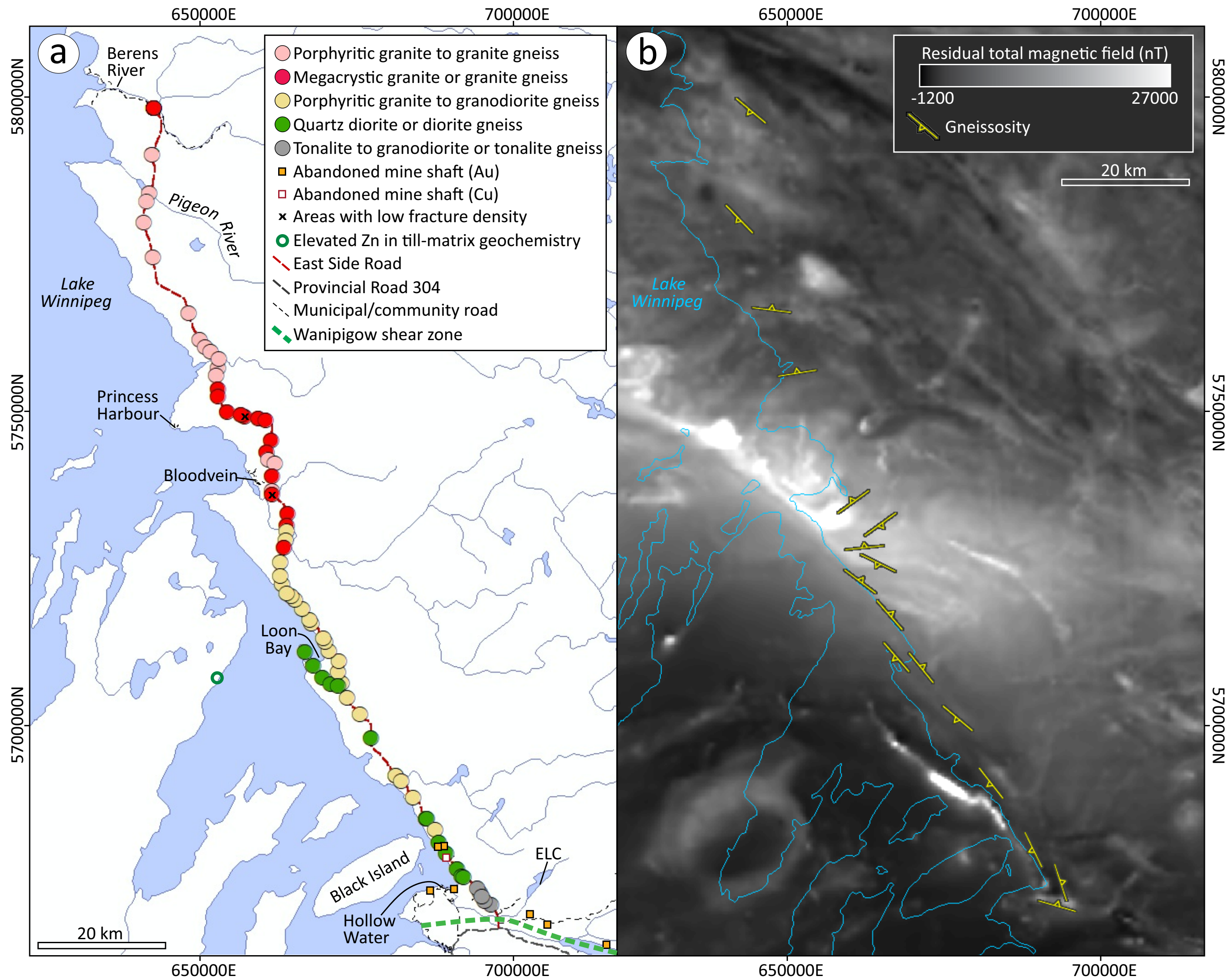


***Figure GS2020-1-1**: Bedrock mapping along East Side Road in southeastern Manitoba showing **a)** 2020 station locations coloured according to dominant rock unit; **b)** greyscale map of the residual total magnetic field, with selected but regionally representative gneissosity measurements (same area as in panel a). First Nation communities and other locations mentioned in the text are labeled. Roads on the western side of Lake Winnipeg are not shown. The elevated Zn value across from Loon Bay refers to a till-matrix (<177 µm-size fraction) analysis with 236 ppm Zn, which far exceeds background values (Hodder and Bater, 2016). The Wanipigow shear zone marks the boundary between the Uchi and Berens River domains. Aeromagnetic data are from Viljoen et al. (1999). Co-ordinates are in UTM Zone 14, NAD83. Abbreviation: ELC, English Lake complex.*

overprinted the older crustal remnants, including voluminous arc magmatism in the Berens River domain at ca. 2.75–2.71 Ga (Percival et al., 2006).

The Uchi domain, forming the southern part of the North Caribou superterrane, includes prolific gold camps such as the Red Lake district in Ontario and the Rice Lake greenstone belt in Manitoba. The southern end of East Side Road traverses only a few kilometres of the Uchi domain; most of the route, including stations described in this report, is located in the southwestern part of the Berens River domain.

Geology of East Side Road

Geological units are described below in estimated order of emplacement, from earliest to latest. Geochronological analyses are planned for several of the 2020 field samples. Although the rocks underwent amphibolite– to lower-granulite–facies metamorphism, the 'meta' prefix is omitted from this report.

Tonalite to granodiorite/tonalite gneiss

Outcrops of tonalite to granodiorite were mapped in the southern part of East Side Road, near Hollow Water First Nation (Figure GS2020-1-1a). The rocks are light grey-beige on most weathered surfaces and light grey to grey-green on fresh surfaces (Figure GS2020-1-2a). They contain abundant phenocrysts of quartz and subhedral to rounded plagioclase 1–5 mm across in a fine-grained groundmass that commonly displays conchoidal fractures. Two outcrops appear slightly pink on weathered surfaces and have sparse phenocrysts of what is

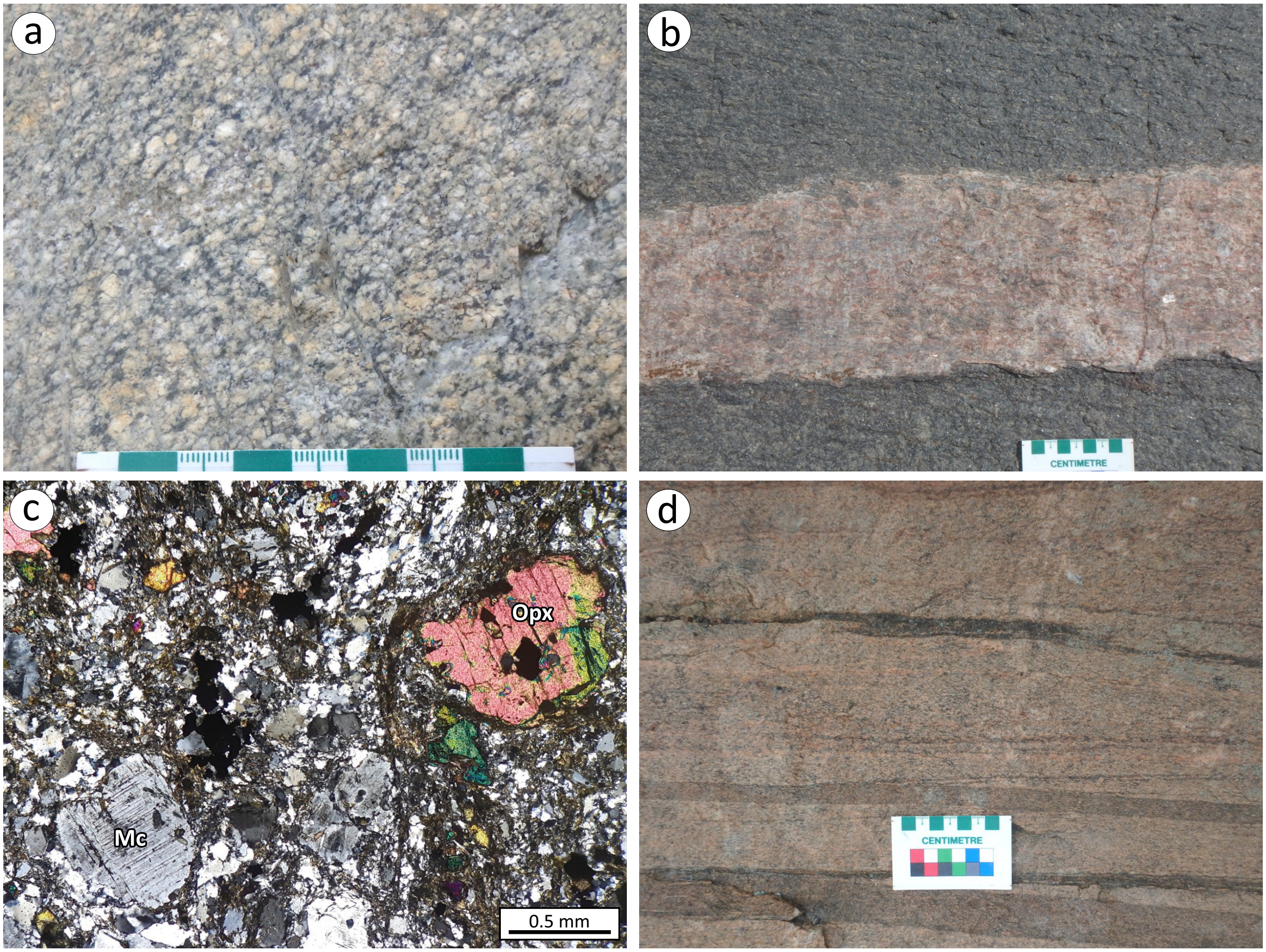


***Figure GS2020-1-2:** Outcrop and thin-section photographs of East Side Road units mapped in 2020, showing **a)** tonalite with rounded plagioclase and smaller quartz phenocrysts on weathered surface (scale in centimetres); **b)** fresh surface of moderately foliated quartz diorite (dark grey) and a medium- to coarse-grained granite dike; **c)** photomicrograph of porphyritic granite with orthopyroxene and microcline in a groundmass consisting mostly of K-feldspar, quartz and biotite (cross-polarized light); **d)** porphyritic granite gneiss from the southern portion of the road, with discrete gneissic bands and possible examples of deformed mafic xenoliths (black streaks). Abbreviations: Mc, microcline; Opx, orthopyroxene.*

likely orthoclase; these were identified in the field as granodiorite. The rocks vary from moderately foliated to gneissic and locally intensely sheared, with mylonitic bands parallel to the gneissosity. Gneissic examples contain quartz and plagioclase phenocrysts preserved as porphyroclasts or augen.

Ermanovics (1981) described small lenses of ultramafic rock hosted within the tonalite near Manigotagan. Ultramafic rocks were not documented during the 2020 fieldwork, except for one thin exposure of serpentine-chlorite–altered cataclasite within faulted tonalite; geochemical results are pending.

Quartz diorite/diorite gneiss

Quartz diorite was mapped along the route directly east of Black Island and extending along the peninsula that forms the western part of Loon Bay (Figure GS2020-1-1a). The diorite is light grey-beige or rarely light grey-green on weathered surfaces and dark grey on fresh surfaces (Figure GS2020-1-2b). It consists of approximately 40–60% quartz and plagioclase phenocrysts (or porphyroclasts in areas of higher strain) 0.5–2 mm across, within a darker grey groundmass containing up to 35% mafic minerals (secondary actinolite, hornblende and minor orthopyroxene). The diorite outcrops vary from moderately foliated to intensely foliated with gneissic layering, which is defined by centimetre-scale variations in mafic-mineral abundance in more strongly deformed outcrops, along with variations in porphyroclast size.

Porphyritic granite to granodiorite gneiss

Porphyritic granite to granodiorite gneiss occupies a large region from near the northern tip of Black Island to near Bloodvein First Nation (Figure GS2020-1-1a). All outcrops of this unit contain gneissic banding, though the banding is in places subtle and more easily identified on large fresh exposures such as roadcuts. The gneiss is typically light pink-grey on weathered surfaces and tan-grey on fresh surfaces. Near Loon Bay, some outcrops contain alternating layers up to 30 cm thick of granitic gneiss and a grey-beige gneiss apparently lacking K-feldspar, interpreted as intermixed layers of the quartz diorite described above.

The granite to granodiorite gneiss contains an assemblage of K-feldspar (microcline and orthoclase, as porphyroclasts), quartz, plagioclase, orthopyroxene, biotite and hornblende, in addition to later (or retrograde) chlorite and calcite (Figure GS2020-1-2c). Trace phases include pyrite and zircon. The orthopyroxene-bearing assemblage is consistent with the findings of Ermanovics (1970, 1973), who noted regional metamorphism ranging mostly from amphibolite– to lower-granulite–facies in the study region.

Driving north of Loon Bay, the gneiss demonstrates a gradual change in overall colour, becoming darker grey especially on fresh surfaces, reflecting a northward increase in the abundance of mafic minerals (biotite, hornblende and orthopyroxene). This change appears to correspond to a regional increase in total magnetic intensity (Figure GS2020-1-1b), although no magnetism was noted in outcrops of the granite to granodiorite gneiss.

Although the overall composition of the unit remains felsic, pronounced gneissic banding within some of the slightly darker outcrops along the northern portion of the road has produced a few isolated layers of dark material that can resemble xenoliths of mafic rock, particularly on small exposures (Figure GS2020-1-2d). These features may correspond to the small zones of "mafic gneiss" described by Ermanovics (1970a, unit 9), though they are distinct from the gabbro unit described below.

Megacrystic granite/granite gneiss

Megacrystic granite was mapped mostly near Princess Harbour and Bloodvein, as well as at a single station at the northern end of East Side Road, at the turnoff toward Berens River First Nation (Figure GS2020-1-1a). The granite is light pink-grey on most weathered surfaces and dark tan-grey to red on fresh surfaces. Most of the rock comprises a groundmass of equigranular to weakly porphyritic granite with quartz and K-feldspar phenocrysts 2–4 mm across and 5 to 20% hornblende and biotite. Scattered subhedral K-feldspar megacrysts 3–8 cm across are distinctive (Figure GS2020-1-3a) and make up between 1 and 15% of the outcrops. Titanite is a common accessory phase in the megacrystic granite, occurring as disseminated euhedral rhombs 0.5–3 mm across, and is in places altered to a distinctive yellow (likely a mixture of calcite and anatase).

The megacrystic granite is generally massive in outcrop, except for local strain partitioning and fracture development, and in places displays a subtle, shallow eastward-plunging linear fabric from the orientation of K-feldspar megacrysts. However, east and south of Bloodvein, the unit occurs as a granite gneiss in which megacrysts are preserved as large (~4 cm) K-feldspar porphyroclasts.

Porphyritic granite to granite gneiss

Porphyritic granite to granite gneiss occupies most of the stretch from Princess Harbour to Berens River and is interpreted as a marginal phase to the megacrystic granite. The granite along the northern part of the road is identical to the groundmass of the megacrystic granite described above (Figure GS2020-1-3b) and contacts with the megacrystic granite appear to be gradational over hundreds of metres on the basis of a decreasing abundance or gradual disappearance of megacrysts between outcrops. Both the megacrystic and the porphyritic granite contain partially assimilated xenoliths of probable diorite (Figure GS2020-1-3c), possibly derived from the quartz diorite unit near Loon Bay.

Gabbro dikes

Gabbro dikes were documented at five locations between Loon Bay and the area east of Black Island, but they do not form a mappable unit. The gabbro is fine-grained and appears dark grey-green on both fresh and weathered surfaces. The dikes range from 2 to 80 cm in width, with sharp contacts transposed parallel to the regional gneissosity, and are commonly boudinaged (Figure GS2020-1-3d), dismembered and folded about axial planes that parallel the gneissosity. The gabbro dikes crosscut the quartz diorite and granite-granodiorite gneiss units, and were themselves cut by late granite dikes.

Granitic pegmatite dikes

Fifteen examples of granitic pegmatite were documented along East Side Road, from Loon Bay to the Pigeon River (Figure GS2020-1-1a). Pegmatite occurs in dikes that range between 5 cm and 3 m in thickness (Figure GS2020-1-4a), with crystals reaching up to 11 cm in length. The mineralogy of the dikes consists of approximately 60% K-feldspar (locally containing perthitic lamellae and graphic quartz intergrowths), 20% quartz, 10% plagioclase, 5–10% biotite and muscovite, trace hornblende and, in a few locations, up to 5% magnetite in aggregates up to 4 cm across (Figure GS2020-1-4b). Secondary chlorite and actinolite (after micas) and epidote and sericite (after feldspars) are also common. Although geochemical data are pending, the mineralogy of these simple pegmatites suggests little potential for pegmatite-hosted rare-metal mineralization (e.g., lithium).

The pegmatite dikes have mostly sharp and irregular margins transposed subparallel to the gneissosity. In the megacrystic granite, a few pegmatite dike contacts appear to be diffuse over several centimetres. In areas of higher strain, particularly

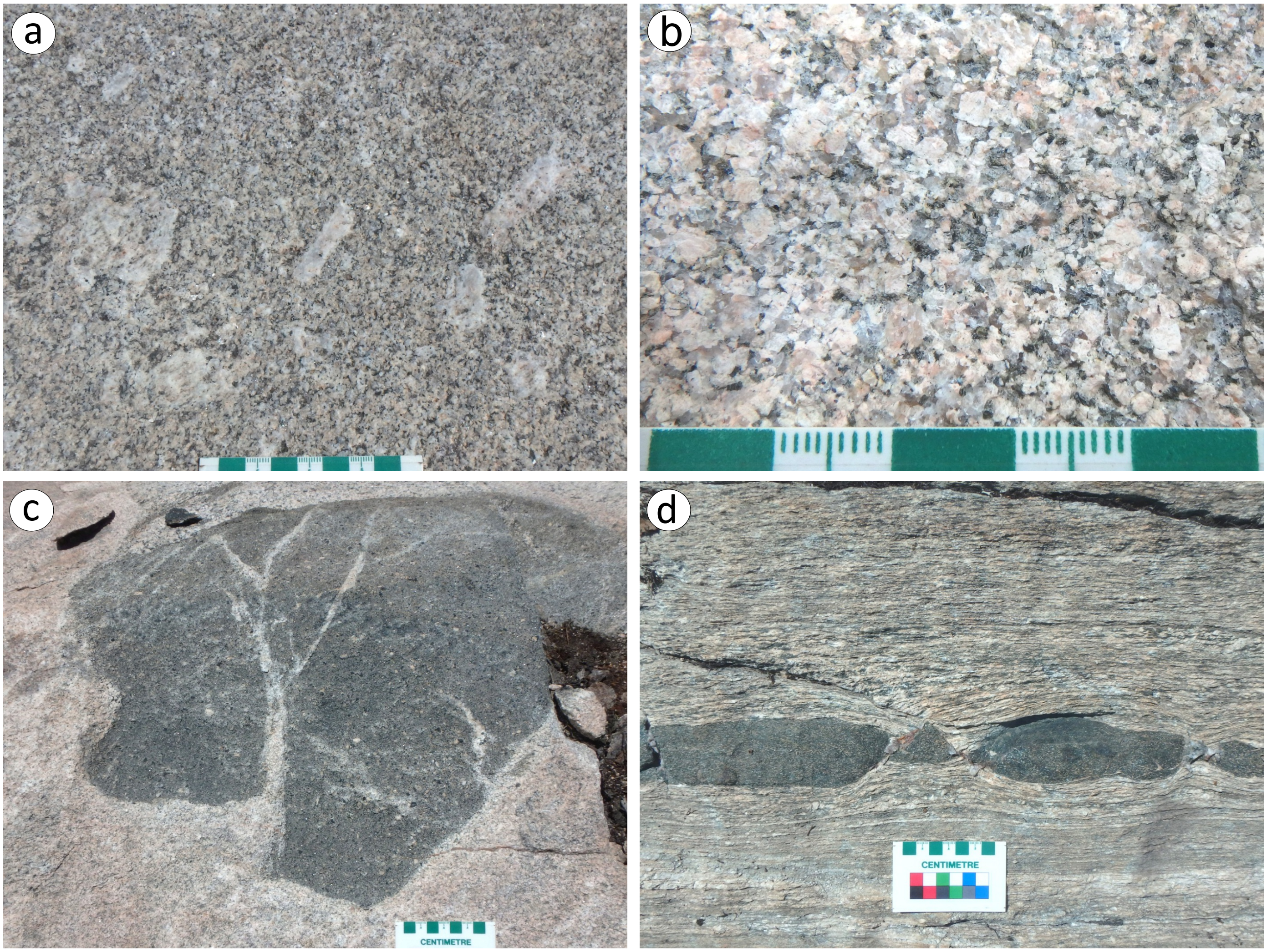


Figure GS2020-1-3: *Outcrop photographs of East Side Road units mapped in 2020, showing* ***a)*** *granite containing K-feldspar megacrysts (scattered throughout image centre) in a coarse-grained granite groundmass (scale in centimetres);* ***b)*** *porphyritic to equigranular granite similar to the groundmass in panel a, with K-feldspar phenocrysts only slightly larger than the surrounding groundmass (scale in centimetres);* ***c)*** *angular quartz diorite xenolith in northern porphyritic granite;* ***d)*** *boudinaged gabbro dike in gneissic quartz diorite.*

around Loon Bay, the pegmatite dikes commonly show grain-size reduction toward dike margins, with micas deformed into seams or stringers, and larger quartz and K-feldspar crystals preserved as porphyroclasts up to 6 cm in diameter.

Granite dikes

Granite dikes are common along the entire length of East Side Road and were found to crosscut all plutonic units as well as the gabbro and granitic pegmatite dikes. The dikes are 1 cm to 2 m thick, with an equigranular to weakly porphyritic texture that ranges from fine- to coarse-grained (Figure GS2020-1-2b). In gneissic outcrops, the dikes were transposed parallel to the gneissosity and are commonly folded about axial planes that parallel the gneissosity. Most of the dikes have sharp, irregular margins; a few exceptions were found in the megacrystic granite, where granite dikes contain contacts that are diffuse over several centimetres into the host granite. Similar features were noted in some of the pegmatite dikes and may imply a coeval relationship (i.e., the dikes represent a late stage of a multiphase granitic intrusion) and/or that the megacrystic granite was hot and plastic during the intrusion of both the granite and granitic pegmatite dikes.

Post-gneissosity granite dikes

Relatively undeformed granite dikes between 1 and 25 cm thick were found at three locations near Bloodvein First Nation. In the field, these dikes are indistinguishable from the granite dikes described above, except that they postdate the development of gneissic banding and folding (Figure GS2020-1-4c), and contain weak K-feldspar alteration haloes. The dikes are fine- to medium-grained and weakly porphyritic, trending north-northwest and dipping steeply to the east.

Structural geology

Most of the outcrops along East Side Road display a well-developed gneissosity in addition to late shears and fractures.

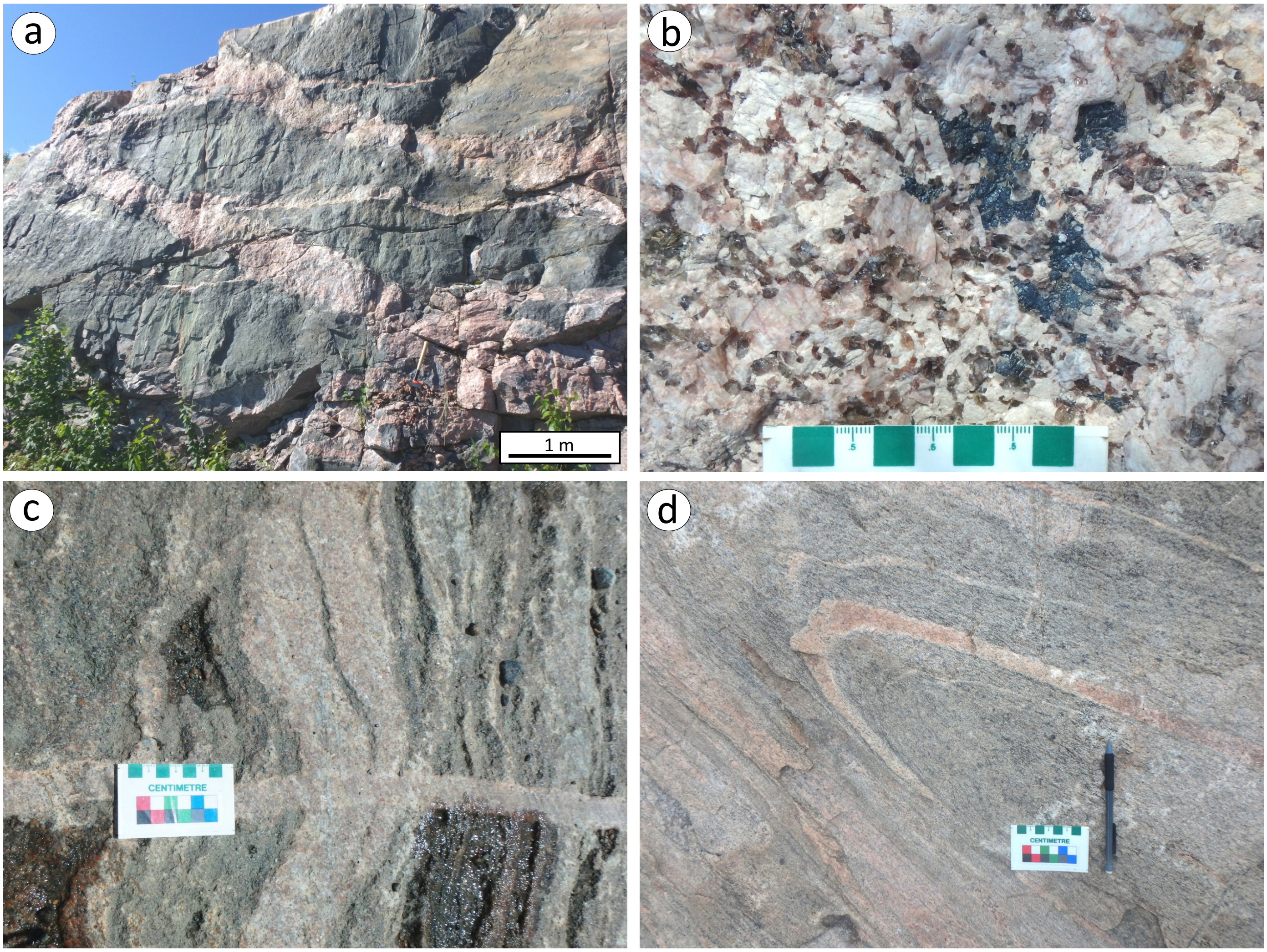


Figure GS2020-1-4: *Outcrop photographs of East Side Road units mapped in 2020, showing* ***a)*** *granitic pegmatite dikes (pink) exposed along a subvertical slickenside face;* ***b)*** *magnetite aggregates (right of centre) within a coarse-grained portion of a granitic pegmatite dike (scale in centimetres);* ***c)*** *megacrystic granite gneiss (containing large porphyroclasts not visible in photo) and a deformed pegmatite dike (vertical pink dike through image centre) crosscut by a post-gneissosity granite dike (horizontal across image);* ***d)*** *tight to isoclinal folds, with axial plane parallel to the regional gneissosity in granite gneiss (pencil pointing north).*

In granitoid rocks, the gneissic banding is defined by the relative abundance of biotite and hornblende. The thickness of the bands correlates mostly with the degree of strain; the most strongly deformed outcrops—especially around Loon Bay and the area east of Black Island—contain bands a few centimetres wide (e.g., Figure GS2020-1-2d) and locally grade into thin (<30 cm) shear zones with mylonite subparallel to the gneissosity. Sigmoid porphyroclasts at several locations record evidence of both sinistral and dextral movement, with no clear prevalence observed in any area. The gneissic banding is also commonly accompanied by tight to isoclinal folds (Figure GS2020-1-4d), with axial planes parallel to the regional gneissosity.

The orientation of gneissic banding varies at outcrop scales, but on average it tends to follow the regional magnetic fabric visible in aeromagnetic data (Figure GS2020-1-1b). In areas south of Loon Bay, gneissosity along East Side Road dips steeply (>70°) and trends generally south-southeast or north-northwest. Driving north from Loon Bay to Bloodvein, the overall strike rotates counterclockwise (Figure GS2020-1-1b), shallowing locally to subhorizontal, and strain gradually decreases into weakly foliated outcrops of megacrystic granite east of Princess Harbour. North of this area and extending up to Berens River, gneissosity is steeply dipping and trends west or southeast, again broadly tracing the regional magnetic fabric.

Small shears were measured at seven locations along the southern half of East Side Road. Both sinistral and dextral shears were noted, which range from 3 to 20 cm in thickness. The shears crosscut the gneissosity and are subvertical, trending generally northeast or south-southeast. Three fault planes were also noted along roadcut faces in the southern half of East Side Road: one fault striking northwest and dipping ~74° northeast in granite gneiss (with slickenside producing the dark surface pictured in Figure GS2020-1-4a); and a further two subvertical faults striking south-southeast in the tonalite near Hollow Water. Slickenside fabric along the fault planes is subhorizontal in all three cases, indicating transfer movement along the south-southeast-trending structures. A section of chlorite- and serpentine-altered cataclasite preserved at one location suggests a minimum fault thickness of 1.5 m. Elsewhere, the thickness of the faults is unclear as only one face was preserved along each roadcut.

Minor joints or fractures are present in every outcrop mapped along East Side Road and are the latest structures documented in the study area. The fractures are approximately 1 mm wide and are slightly undulating. Preliminary measurements indicate four dominant fracture orientations: one set striking ~225° and dipping 55–85°; a second at ~300° and subvertical; a third at ~75° and subvertical; and a fourth set of subhorizontal fractures. The combination of these fracture orientations typically results in blocky faces along roadside outcrops.

Most outcrops contain abundant fractures spaced at most a few metres apart. However, two large exposures near East Side Road (marked by × symbols in Figure GS2020-1-1a) were found to contain only sparse fractures, in places between 20 and 40 m apart. These flat outcrops of megacrystic granite and granite gneiss contain few vertical exposures; therefore, subhorizontal fractures may be underrepresented. The apparently low fracture density may make these rocks suitable for dimension stone (e.g., polished granite slab) quarrying.

Economic considerations

East Side Road provides a small transect through the southwestern part of the Berens River domain. Several features in this area indicate potential for mineral resources, most notably

- Dimension stone quarries can be economically viable in areas with appropriate rock types, low fracture density and proximity to transportation infrastructure (e.g., Schmidtke, 1994). Preliminary findings along East Side Road point to two areas (Figure GS2020-1-1a) in which these conditions may be met.
- Gold is a substantial resource in the Rice Lake belt of the Uchi domain. North of the Wanipigow shear zone, shears through granitoid rocks of the Berens River domain are host to several gold occurrences and deposits, mostly east of the area shown in Figure GS2020-1-1a. Results of the 2020 reconnaissance mapping did not point to alteration or major structures with obvious connections to lode-gold mineralization. Further investigation may be warranted, as there are limited records concerning historical gold (±copper) mine shafts near the southern parts of East Side Road (Figure GS2020-1-1a).
- Pegmatite-associated rare-metal mineralization has been discovered in parts of the Superior province both north and south of the study area, though most known occurrences and deposits are hosted in granite-greenstone (as opposed to granitoid-dominated) domains. Granitic pegmatite dikes are common along East Side Road, but all appear to be simple pegmatites with little potential for rare metals. These results do not discount the potential for mineralized pegmatites elsewhere in the Berens River domain.
- Base-metal deposits, including zinc, are unlikely in granitoid-dominated regions such as the Berens River domain. However, an elevated zinc value in till matrix collected along the southwestern shore of Lake Winnipeg could imply a source to the northeast (up ice), potentially across the study area. Depending on the size of the possible dispersal train, there is a chance that upcoming till geochemistry results from the East Side Road project (Gauthier and Hodder, 2020) can help to resolve the anomaly.
- Ultramafic intrusions have been mapped along and near the northern flank of the Rice Lake belt, including the nickel- and copper-mineralized English Lake complex (ELC in Figure GS2020-1-1a; Assessment File 73929). Although no ultramafic units were encountered along East Side Road (with the possible exception of one thin exposure of serpentine- and chlorite-altered cataclasite), there is related, albeit minor, potential for nickel-copper mineralization near the southern part of East Side Road.
- There is currently little information to assess diamond potential along East Side Road. The Berens River domain represents old crust that was formed prior to the accretion of much of the rest of the Superior province; such conditions can be favourable for diamond formation. Kimberlite indicator mineral analyses of till samples collected this summer (Gauthier and Hodder, 2020) could inform future studies on diamond potential in the area.

Acknowledgments

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GS2020-2

Progress report on updates to the Manitoba Mineral Deposits Database, east-central Manitoba (NTS 53E, F)

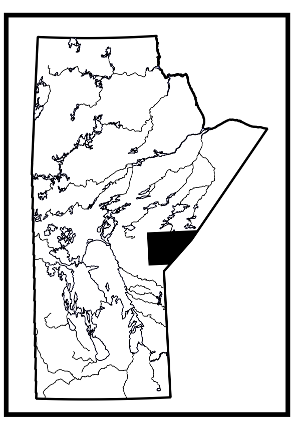
by M.L. Rinne

In Brief:

- Known mineral occurrences are not fully captured in Manitoba's Mineral Deposits Database
- Gaps in occurrence data are being filled from several sources, including assessment files and geochemical datasets
- First set of updates has so far resulted in approximately 100 new occurrences (and 150 updates to existing occurrences) added to the Island Lake region

Citation:

Rinne, M.L. 2020: Progress report on updates to the Manitoba Mineral Deposits Database, east-central Manitoba (NTS 53E, F); *in* Report of Activities 2020, Manitoba Agriculture and Resource Development, Manitoba Geological Survey, p. 9–12.



Summary

In 2020, the Manitoba Geological Survey (MGS) began work to update Manitoba's Mineral Deposits Database (MDD), mostly through reviews of historical datasets, including assessment reports. This report describes the rationale, methods and the intended product of the MDD update project, along with preliminary results from the first round of updates for NTS map sheets 53E and F. Comprehensive mineral occurrence data are fundamental to land-use and economic development planning, and are routinely used by the minerals sector to guide its increasingly data-driven mineral exploration decisions.

Introduction

The implementation of land-use plans and mineral development strategies in any jurisdiction requires an accurate understanding of the locations and characteristics of its known mineral occurrences. In its present form, the MDD provides an extensive digital inventory of mineral deposits and occurrences in Manitoba. However, compilation work by MGS geologists has revealed errors in some regions as well as significant omissions of known occurrences. An MDD update committee was established in 2020 to define the steps needed to improve the database, and the overall strategy defined by the committee is outlined in this report. Although historical data have not been fully reviewed for the first area selected for updates, this report provides a summary of mineral occurrences added so far to NTS map sheets 53E and F.

Project rationale and methodology

The MDD is currently an Oracle®[1] database first published by the MGS in 2009 (Conley et al., 2009) and is the most recent version of a mineral occurrence or deposit inventory in Manitoba. It was compiled from two analogue archives—the Mineral Inventory Cards database and reports of the Mineral Deposit Series (Heine, 2007)—and is available through Manitoba Mineral Resources' online Map Gallery. Although the MDD represents an important and clearly necessary improvement to the previous paper archives, it remains incomplete; information contained in assessment files, for example, is in some regions entirely absent or only partially represented in the current database. Whole-rock geochemical datasets from various sources will also allow for the inclusion of commodities—including some critical minerals—not captured in the existing MDD.

The main goal of this project is to update the MDD by adding missing data from sources including assessment files and, to a lesser extent, by correcting errors in some existing entries. The intended product is a more comprehensive and accurate inventory of mineral occurrences in Manitoba, allowing for better informed assessments of mineral resource potential.

Definitions

A mineral occurrence is defined as a concentration of a commodity or mineral (e.g., gold, lithium or graphite) of scientific or economic interest (Cox and Singer, 1986). A mineral deposit is an unusually large or high-grade occurrence that demonstrates potential to be extracted at a profit.

For the purposes of updating the MDD, geochemical results from surface or drillcore samples are considered to represent an occurrence where values exceed defined limits. Most of these minimum-grade criteria are the same as in Ontario's equivalent database (the Ontario Mineral Deposit Inventory; Ontario Geological Survey, 2020); some examples are listed in Table GS2020-2-1. Occurrence criteria for some commodities (e.g., lithium, rare earth elements) are to be determined.

[1] Oracle and Java are registered trademarks of Oracle and/or its affiliates. Other names may be trademarks of their respective owners.

Table GS2020-2-1: Selected examples of minimum-grade or mineral criteria for occurrences.

Commodity	Minimum-grade or mineral content requirement
Au	0.5 ppm (0.5 g/t or 0.015 oz/ton) or visible gold
Ag	35 ppm
PGE (Pt+Pd+Rh+Ir+Ru+Os)	0.7 ppm
Cu	2500 ppm (0.25%)
Zn	5000 ppm (0.5%)
Pb	10 000 ppm (1%)
Ni	800 ppm
Co	200 ppm
Mo	800 ppm
Mn	50 000 ppm (5%)
W	790 ppm
TiO_2	7.50%
U_3O_8	0.03% or minerals present
Diamond	Minerals present
Graphite	5% or present as coarse flakes or seams

During their review of historical data, MGS geologists may encounter descriptions or geochemical results that do not strictly meet the requirements described above but are deemed to be of likely interest to MDD users; such cases would be classified as 'discretionary occurrences' in the MDD updates.

Data sources

Mineral occurrence data are being extracted from several sources. Assessment files held by the Government of Manitoba contain reports of work done by mineral exploration companies in the province since the 1930s. Over 9000 reports are currently available and will provide the majority of the data for new MDD entries. Scans of the assessment reports to PDF are generally sufficient for MDD updates, though originals must be retrieved from the Assessment Library in some cases, such as when extracting surface-sample location data from large hand-drawn maps. Confidential assessment data and/or files submitted less than three years ago cannot be included in MDD updates for public release, but equivalent information may in some cases be obtained from publicly available documents such as company press releases.

Various surface and drillcore geochemical datasets will be reviewed for new MDD entries, including Data Repository Items (DRIs) released by the MGS (e.g., Rinne, 2020), surface-sample data collected during regional mapping by the Geological Survey of Canada (e.g., Ermanovics et al., 1975) and compilations such as the Canadian Database of Geochemical Surveys (Natural Resources Canada, 2020). These whole-rock geochemical datasets commonly include certain commodities (e.g., lithium, cobalt) that are underrepresented in the assessment file data.

Methods

Given the volume of data to be reviewed and added, most new mineral occurrence entries will include only a unique identifier (MDD number), location data, relevant assay/geochemistry values (and/or minerals observed), and drillhole and assessment file information, where applicable. Several of the more detailed columns or fields in the existing MDD entries—such as geological descriptions and summaries of past exploration relating to each occurrence—will be left blank in new entries, with the exception of major deposits or new mine developments. Additionally, for each commodity reported in drillcore, only the highest assay value from each drillhole is initially recorded; any values meeting the occurrence classification requirements are then marked as occurrences at drill collar locations rather than projected vertically to surface. Although this compromised approach captures only the key characteristics necessary to inform regional land-use planning or to trigger interest in mineral resource potential, it allows for faster releases of new updates. If more detailed information is needed, end users can examine the publicly available sources of data (e.g., assessment files) referenced for each occurrence.

Reports in the assessment files do not have a consistent format, which complicates attempts to automate the data-gathering process. However, it may be possible to improve the efficiency of data gathering by using optical character recognition in some of the scanned reports.

Release format

The MDD is being migrated from an Oracle® database to a Microsoft® Access® database. The overall structure of the original database will be preserved in the updated MDD, including reference to a unique MDD number. Although most new entries in the MDD will contain less detailed information (such as exploration history or geological descriptions) than in most of the existing entries, existing fields will not be removed. Moving forward, new assessment data will also be added regularly by the Assessment and Consultation Geologist.

Updates to the MDD will be released by region (i.e., NTS 1:250 000 map sheet) rather than sporadically throughout the province. Until a version of the Microsoft® Access® database is finalized, regional updates will be released to the public in a simplified format as DRIs.

Results to date

Map sheets NTS 53E and F, covering much of the Island Lake domain of the northern Superior province, were selected for the first MDD update. Excluding parts in Ontario, the region contains approximately 650 drillholes and is the subject of 150 assessment files, with most of the reported work focused on the Island Lake and Bigstone Lake greenstone belts.

Since beginning the MDD update this year, a total of 247 mineral occurrences have been identified from review of industry and government sources. Pending additional review, several of the new occurrences may be grouped together. Most of the occurrences updated in the Island Lake greenstone belt were already included in some form in the previous MDD, although several were lacking grade or commodity information. Apart from a single zinc occurrence, all the occurrences added to the Bigstone Lake greenstone belt are new entries (Figure GS2020-2-1).

Among the new occurrence data added, notable examples are listed below, numbered as indicated in Figure GS2020-2-1:

1) Several shear-hosted gold veins occur near the eastern shore of Bigstone Lake, including the Diamond Queen veins discovered in the 1930s (Assessment File 91148, Manitoba Agriculture and Resource Development, Winnipeg) and a nearby series of veins discovered in 2017 across a 1 by 2 km area, with several surface samples containing greater than 30 ppm Au (Rinne, 2017; 2020).
2) East of the Diamond Queen veins, gold mineralization is distributed along an approximately 16 km south-southeast trend through the centre of the Bigstone Lake greenstone belt. Occurrences along this trend are from both surface and drillcore samples, with grades of up to 80.6 ppm Au. Along with the Diamond Queen veins, these gold occurrences are spatially associated with regional silicification and calcite alteration (Rinne, 2017, 2019).
3) There are several minor nickel (±copper) occurrences scattered across the southwestern part of the Bigstone Lake

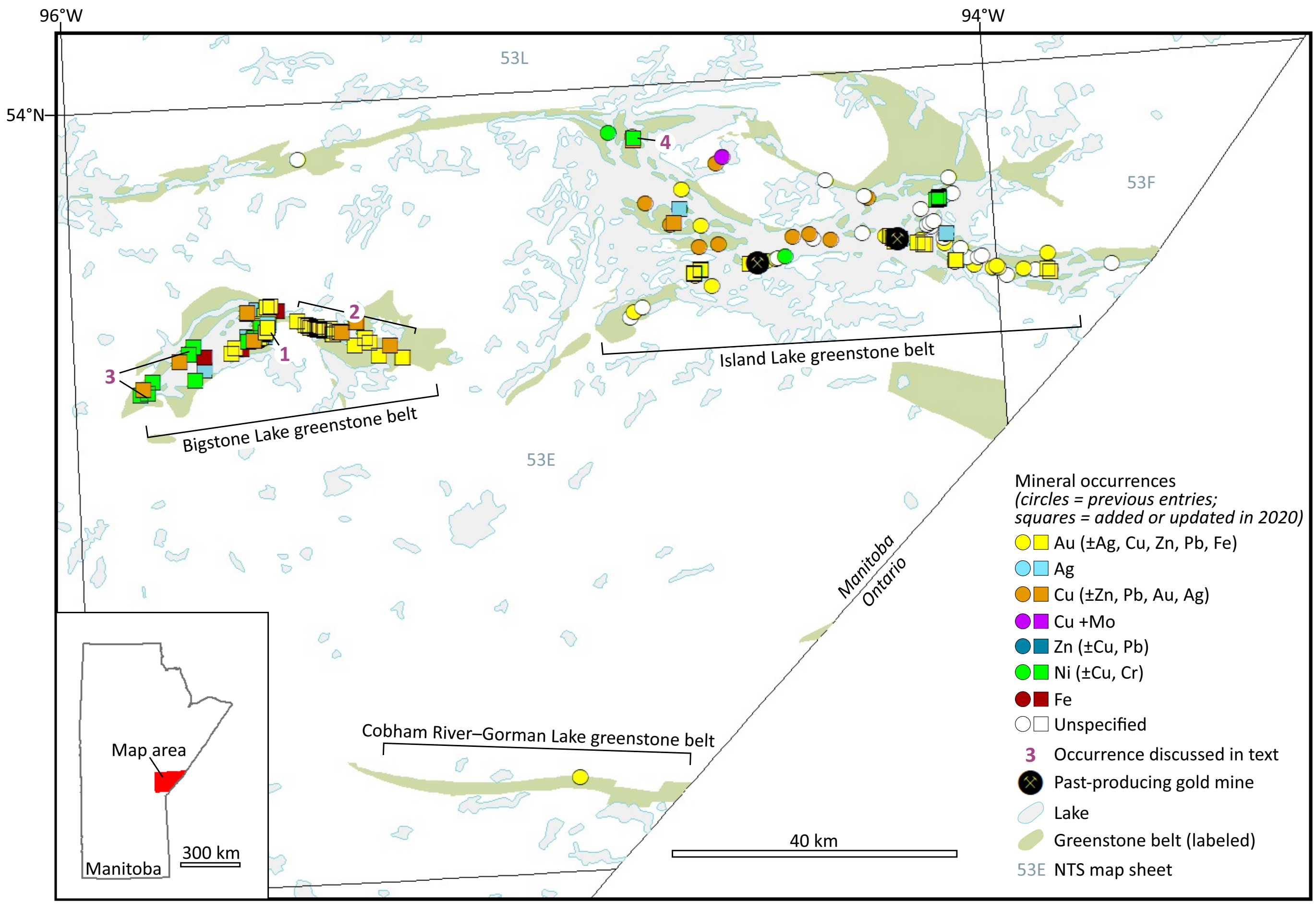


Figure GS2020-2-1: *Mineral occurrences in NTS map areas 53E and F, including new data added in 2020.*

greenstone belt. Most are from unmineralized or weakly mineralized peridotite and komatiitic basalt sampled in 2016 and 2017 (Rinne, 2020). One of the nickel occurrences corresponds to a sulphide-mineralized drillcore interval with 0.33% Ni (drillhole BS-73-3d, Assessment File 93492).

4) Additional data were added to the Nickel Island occurrence in the western part of the Island Lake greenstone belt. The existing MDD entry in this area reports up to 6800 ppm Ni, whereas recently added data includes drilling results from the 1950s with up to 2.88% Ni and 0.27% Cu (Assessment File 99325). Wolfden Resources Corporation also noted higher nickel grades (4.33% over 4.5 m) and potential for platinum-group elements at the Nickel Island occurrence.

Economic considerations

Filling gaps in Manitoba's mineral occurrence data will allow for more accurate assessments of the potential for specific commodities in different parts of the province. This type of information is necessary for the design and implementation of land-use and economic development plans (e.g., parks and infrastructure planning within government, geological survey project planning or community economic development strategies). In the private sector, collection and interpretation of geological data plays a central role in mineral exploration decisions, and the release of new (or previously unrecognized) mineral occurrence data may inform renewed exploration efforts in some regions. Furthermore, as artificial intelligence or machine learning techniques are increasingly applied by the mineral resources industry, the MGS anticipates a growing reliance on large datasets such as the MDD.

Acknowledgments

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GS2020-3

Investigation of zirconium- and light rare-earth element–enriched rocks in drillcore from the Huzyk Creek property, sub-Phanerozoic Kisseynew domain, central Manitoba (NTS 63J6)

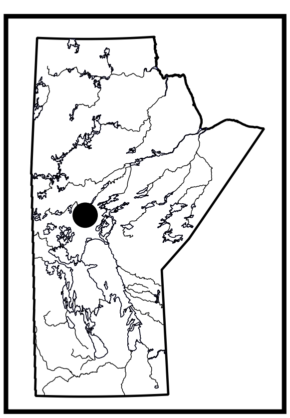
by C.G. Couëslan

In Brief:

- A study was initiated to investigate an occurrence of hornblende granite in drillcore at the Huzyk Creek property, which is enriched in Ba, Sr, Zr, and light rare-earth elements
- The hornblende granite could be related to A-type granite magmatism or post-orogenic alkaline-affinity magmatism
- There could be potential for Zr and/or rare-earth element mineralization in the area; however, further study is required

Citation:

Couëslan, C.G. 2020: Investigation of zirconium- and light rare-earth element–enriched rocks in drillcore from the Huzyk Creek property, sub-Phanerozoic Kisseynew domain, central Manitoba (NTS 63J6); *in* Report of Activities 2020, Manitoba Agriculture and Resource Development, Manitoba Geological Survey, p. 13–20.



Summary

A study was initiated to investigate an occurrence of hornblende granite in drillcore at the Huzyk Creek property. It is enriched in Ba, Sr, Zr and light rare-earth elements, and may be metasomatized. The hornblende granite is hosted in interlayered hornblende gneiss and calcsilicate rock that is interpreted as metamorphosed and variably altered mafic rock. The hornblende granite occurs as relatively small dikes (<10 m) that contain hornblende, biotite, titanite and sulphide. Two additional rock types that could be metasomatic phases were identified: 1) sulphide- and titanite-rich calcsilicate, and 2) bleached rock. The sulphide- and titanite-rich calcsilicate is texturally and mineralogically variable, and may have multiple origins. Only one example of the bleached rock was identified and it appears to crosscut fabrics and structures in the hostrock. Further work is required to determine the affinity of the hornblende granite and the significance of the sulphide- and titanite-rich calcsilicate and bleached rock. The hornblende granite could be related to A-type granite magmatism or postorogenic alkaline-affinity magmatism. If either of these scenarios is confirmed, it could indicate potential for Zr, Nb, Y and/or rare-earth element mineralization in the area.

Introduction

A project was initiated in 2019 to investigate the origins of V-enriched graphite mineralization in drillcore from the Huzyk Creek property (Beaumont-Smith, 2018; Couëslan, 2019, 2020; Vanadian Energy Corp., 2019). During this investigation, a sample of (possibly metasomatized) granite from drillcore HZ-19-1 was found to contain elevated concentrations of Ba, Sr, Zr and light rare-earth elements (LREE; Couëslan, 2020). A new study was initiated in 2020 to determine the extent and nature of the enriched rocks. During the 2019 investigation, the drillcore was logged by attempting to discern the original protolith of the high-grade gneisses through the metamorphic and magmatic overprint. In 2020, a portion of drillcore HZ-19-1 was revisited to look specifically at intrusive phases and possible metasomatic overprint.

Regional geology

Although the Huzyk Creek property overlies the boundary between the Thompson nickel belt and the Kisseynew domain, the stratigraphy, lithogeochemistry and Sm-Nd isotope geochemistry indicate that drillholes HZ-19-1 and HZ-19-2 intersect rocks of the sub-Phanerozoic Kisseynew domain (Figure GS2020-3-1; Couëslan, 2020). The Kisseynew domain is situated in the core of the juvenile Reindeer zone of the Paleoproterozoic Trans-Hudson orogen (THO). It is underlain by dominantly Burntwood group rocks, with subordinate calcalkaline plutons and sheets of anatectic granitoids. The Burntwood group forms a monotonous sequence of graphite-bearing metagreywacke-mudstone, which was metamorphosed to garnet-biotite gneiss and migmatite throughout much of the Kisseynew domain during the terminal collision of the THO. The metagreywacke-mudstone is interpreted as turbidite deposits shed from the surrounding juvenile accretionary-arc complexes of the Flin Flon and Lynn Lake domains (Ansdell et al., 1995; Zwanzig and Bailes, 2010). Coeval fluvial-alluvial deposits on the margins of the Flin Flon and Lynn Lake domains make up the Missi and Sickle groups, respectively (Stauffer, 1990; Zwanzig and Bailes, 2010). The Kisseynew paleobasin is generally interpreted as a back-arc basin; however, an inter-arc or fore-arc basin environment is also possible (Ansdell et al., 1995; Zwanzig, 1997; Corrigan et al., 2009; Zwanzig and Bailes, 2010).

Sub-Phanerozoic Kisseynew domain

The sub-Phanerozoic Kisseynew domain is the southern extension of the Kisseynew domain below the Phanerozoic cover (Figure GS2020-3-1). Situated between the Superior craton margin

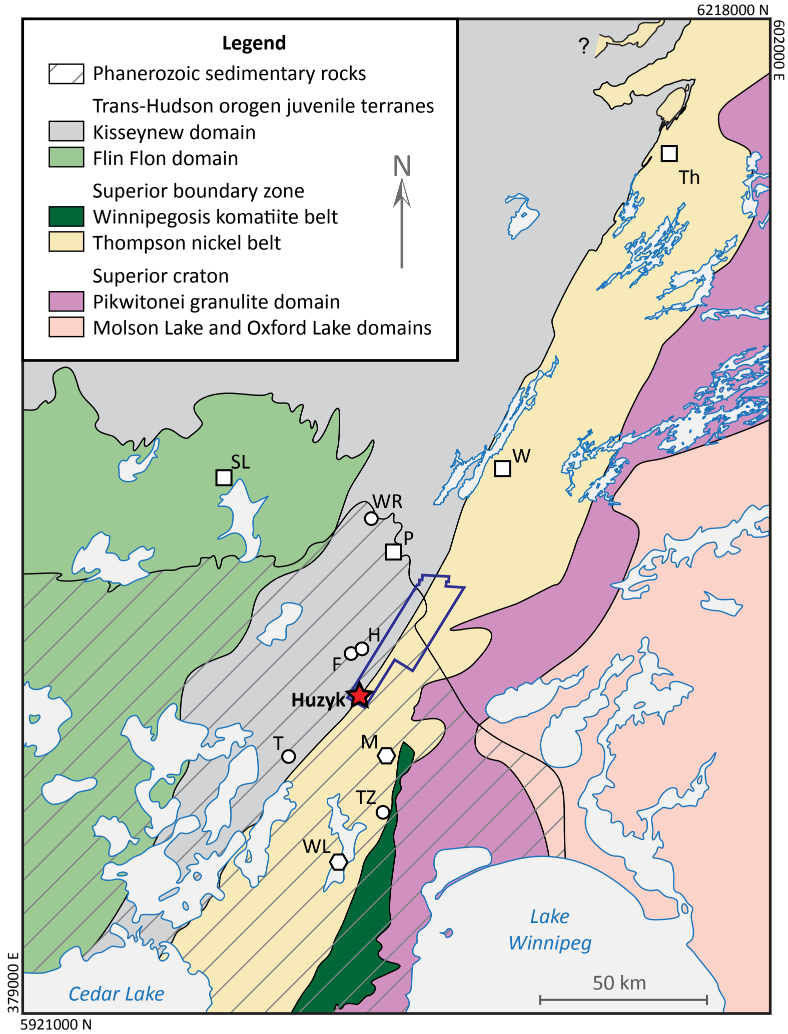


Figure GS2020-3-1: *Geological domains along the Superior boundary zone, central Manitoba (Couëslan, 2020). The dark blue outline is the approximate location of the Huzyk Creek property of Vanadian Energy Corp. Symbols: circles, Cu-Zn deposits in the sub-Phanerozoic Kisseynew domain and Superior boundary zone; hexagons, Ni-Cu deposits/occurrences in the sub-Phanerozoic Thompson nickel belt; squares, town/city/locality; star, location of the 2019 diamond-drilling campaign at the Huzyk Creek property. Abbreviations: F, Fenton deposit; H, Harmin deposit; M, Minago deposit; P, Ponton; SL, Snow Lake; T, Talbot deposit; Th, Thompson; TZ, Tower zone deposit; W, Wabowden; WL, William Lake occurrence; WR, Watts River deposit. Co-ordinates are in UTM Zone 14, NAD83.*

and the Flin Flon domain, it was interpreted to consist of migmatitic metasedimentary rocks of the Burntwood group interlayered with felsic metaplutonic veins and sheets (Leclair et al., 1997). However, the discovery of several volcanogenic massive sulphide (VMS) deposits (Watts River, Harmin, Fenton and Talbot) in the domain has brought this interpretation into question (Simard et al., 2010). Recent studies (Simard et al., 2010; Bailes, 2015; Reid, 2018) suggest complex structural interleaving of Flin Flon domain arc rocks, Kisseynew domain Burntwood group rocks and possibly Thompson nickel belt rocks within the sub-Phanerozoic Kisseynew domain. A similar situation occurs along the north, south and east flanks of the exposed Kisseynew domain, where thrusts and recumbent folding have structurally interleaved rocks of the Kisseynew basin with rocks of adjacent juvenile volcano-plutonic terranes and evolved Archean crust (Zwanzig, 1999; Rayner and Percival, 2007; Zwanzig and Bailes, 2010).

Geology of the Huzyk Creek drillcore

The core from two drillholes (HZ-19-1 and HZ-19-2) was logged in August of 2019 to investigate V-enriched graphite mineralization on the property. The Huzyk Creek drillcore consists of a hornblende gneiss and calcsilicate package in contact, and locally interleaved, with a wacke-mudstone suite containing the V-enriched graphite mineralization (Figure GS2020-3-2). The hornblende gneiss and calcsilicate rock occur at the top of the Precambrian in both drillholes; however, the stratigraphic younging direction is not known. The gneiss and calcsilicate can be interlayered on scales ranging from <1 cm to 2.5 m, with diffuse contacts (Figure GS2020-3-3a). They are interpreted as variably altered mafic rocks, possibly basalt, and may be related to Missi-age, successor-arc magmatism (Couëslan, 2020). In drillhole HZ-19-1, the hornblende gneiss and calcsilicate are interleaved with the underlying wacke-mudstone at

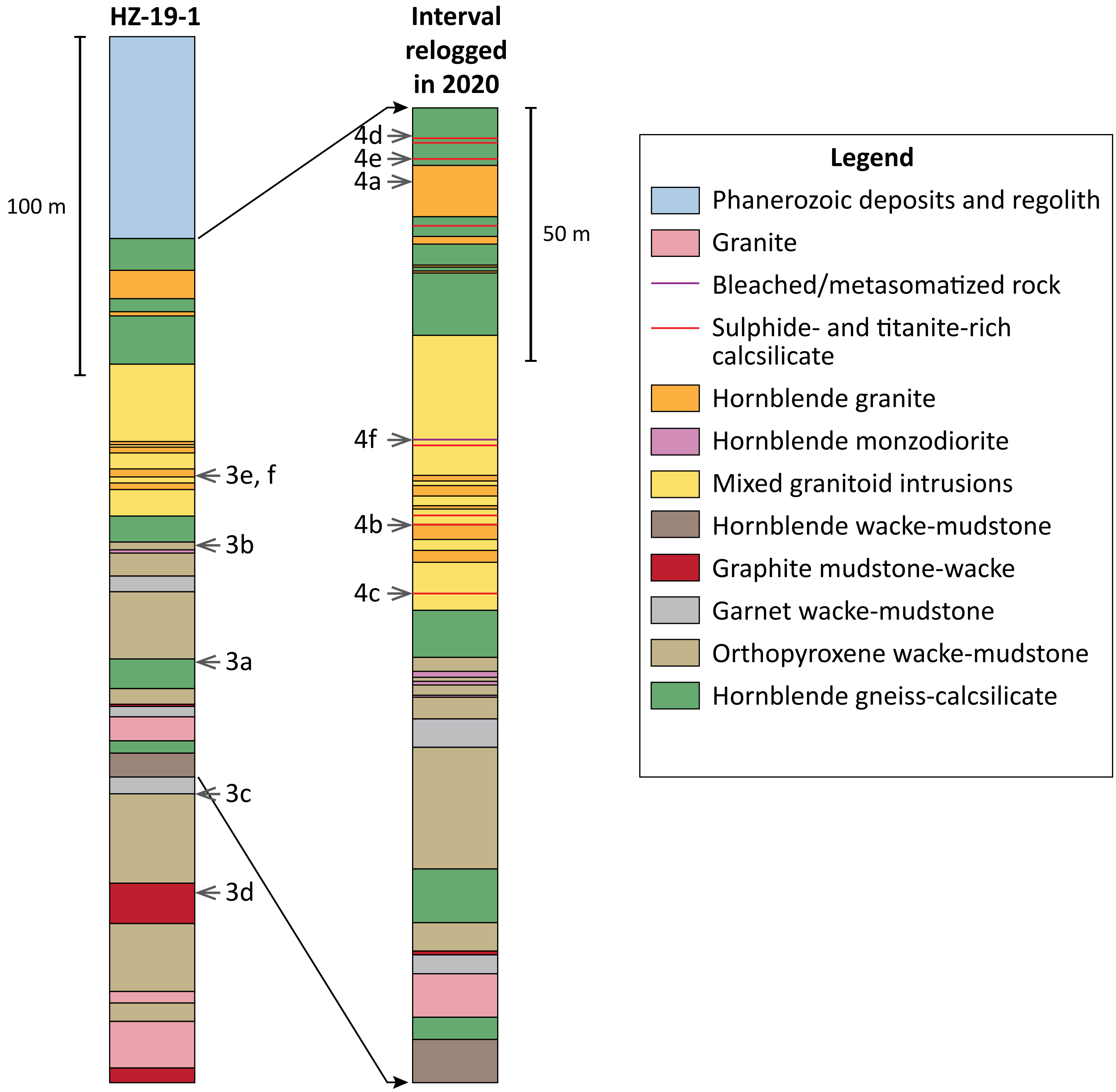


Figure GS2020-3-2: *Schematic logs of drillcore HZ-19-1 from the Huzyk Creek property, including a more detailed section of the interval that was revisited in 2020. Thicknesses of sulphide- and titanite-rich calcsilicate, and bleached/metasomatized rock are not to scale. The stratigraphic positions of images in Figures 3 and 4 are indicated along the inside edge of each column.*

a scale of 2.6–35 m. A preserved contact between calcsilicate and the wacke is sharp with no significant change in strain across the contact (Figure GS2020-3-3b). This may suggest a contact that is stratigraphic rather than tectonic (faulted). The wacke-mudstone package consists of migmatitic gneisses that are subdivided according to the dominant mafic mineral other than biotite. They consist of orthopyroxene wacke-mudstone with subordinate garnet wacke-mudstone (Figure GS2020-3-3c) and graphite mudstone (Figure GS2020-3-3d), and rare hornblende wacke-mudstone. The various wacke-mudstone units are interlayered at a scale of <1 cm to several metres, with the exception of the graphite mudstone that occurs as a discrete horizon roughly 15 m thick. The wacke-mudstone package appears to be related to the Burntwood group of the Kisseynew domain and was likely deposited relatively proximal to the Flin Flon arc-collage (Couëslan, 2020).

The gneisses outlined above were intruded by several types of felsic rocks ranging from tonalite to granite. The intrusions range in size from several centimetres up to roughly 20 m. All intrusions have a well-defined foliation except for a coarse-

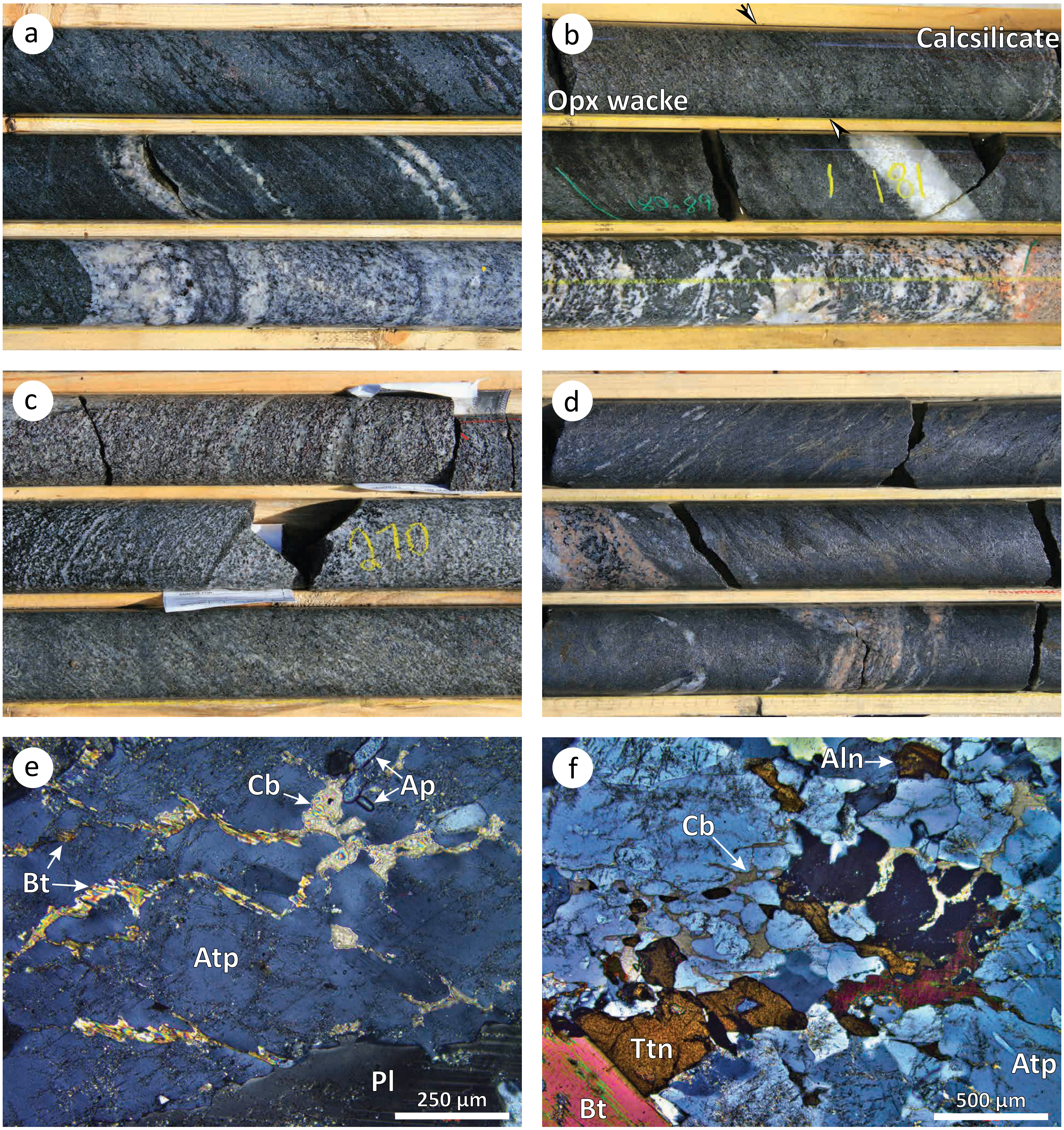


Figure GS2020-3-3: *Drillcore and thin-section images of rocks from drillhole HZ-19-1:* ***a)*** *diffusely interlayered calcsilicate and hornblende gneiss (top two rows; 221.65 m);* ***b)*** *contact between orthopyroxene wacke and calcsilicate (top row, marked with arrows), interlayered calcsilicate and hornblende gneiss (middle row), and quartz monzodiorite (bottom row; 179.4 m);* ***c)*** *interbedded garnet wacke (top row) and orthopyroxene wacke (bottom row; 268.5 m);* ***d)*** *graphite mudstone (HZ-19-1, 303.2 m);* ***e)*** *photomicrograph in cross-polarized light of hornblende granite (sample 108-19-HZ22) with carbonate and biotite microveinlets crosscutting antiperthitic plagioclase; and* ***f)*** *photomicrograph in cross-polarized light of carbonate microveinlets with associated titanite and allanite. Abbreviations: Aln, allanite; Ap, apatite; Atp, antiperthite; Bt, biotite; Cb, carbonate; Opx, orthopyroxene, Pl, plagioclase; Ttn, titanite.*

grained hornblende granite that is locally weakly foliated, and a medium-grained biotite granite that is weakly foliated to massive. A thin section of the hornblende granite revealed microveinlets of carbonate and biotite (Figure GS2020-3-3e), the partial replacement of plagioclase and hornblende by biotite and carbonate, and a close association of titanite and allanite with the biotite and carbonate (Figure GS2020-3-3f). Relatively coarse antiperthite is common, along with zones of myrmekite. The veinlets, replacement textures and feldspar-exsolution textures suggest the granite was metasomatically overprinted. The metasomatized granite was found to be enriched in Ba (14 300 ppm), Sr (3717 ppm), Zr (1304 ppm) and LREE (1303 ppm), and is geochemically similar to metasomatic rocks associated with syenite complexes elsewhere in the Reindeer zone of Manitoba (e.g., the Burntwood, Brezden and Eden Lake intrusive complexes; Martins, 2016a–c; Couëslan, 2020).

Relogging results

Approximately 190 m (from 71.5 to 262.9 m) of drillcore HZ-19-1 was relogged and sampled in July 2020 (Figure GS2020-3-2). The focus of this study was to document the hornblende granite and possible evidence of related metasomatic overprint in the core. Although definitive examples of metasomatism are rare, two phases of potential interest were recognized in the core: sulphide- and titanite-rich calcsilicate, and a bleached rock. These phases, along with the hornblende granite, appear to be restricted to the upper 116 m of the Precambrian (from 71.5 to 187.3 m). The significance of these phases remains uncertain pending geochemical and petrographic analyses. In addition, samples of other granitoid rocks were collected for geochemical comparison with the hornblende granite. Reported thicknesses in this report are intersection lengths, not true thicknesses.

Hornblende granite

The hornblende granite occurs from the top of the Precambrian (71.5 m) to 160.6 m as dikes up to 10 m but typically <3 m. The granite is pink to grey, coarse grained and weakly foliated (Figure GS2020-3-4a, b). Biotite, hornblende and clinopyroxene, combined, typically make up less than 10% of the rock, along with minor titanite and sulphide; however, the granite can locally contain up to 5% pyrrhotite, 7% titanite and 20% hornblende and clinopyroxene. Biotite locally occurs as rims on hornblende grains. The hornblende granite is petrographically similar to some intrusive phases associated with the Burntwood, Brezden and Eden Lake intrusive complexes of the THO of Manitoba (Couëslan, 2005; Martins, 2016a–c). A sample of the hornblende granite collected in 2019 displayed evidence of metasomatism in thin section and was found to be geochemically similar to metasomatized rocks from the intrusive complexes listed above, including elevated Ba, Sr and La/Yb. However, no obvious evidence for metasomatism is visible in the drillcore, and slight geochemical differences (including enrichment in Zr) may be more suggestive of an A-type granite affinity (Chakhmouradian, pers. comm., 2020).

A second variety of hornblende-bearing granitoid occurs from 182.0 to 187.3 m as dikes <1.2 m thick. The dikes are pale pink to greenish white, coarse grained and foliated (Figure GS2020-3-3b). They are mineralogically similar to the hornblende granite but are relatively poor in quartz (quartz monzonite/quartz monzodiorite?) and contain trace amounts of ilmenite rather than titanite. It is uncertain if the two varieties of hornblende-bearing granitoids are related.

The close association between the hornblende granite and the hornblende gneiss and calcsilicate suggests that the granite could represent a granitoid phase that was contaminated by the country rock via partial digestion or xenocryst entrainment. However, this would not explain the enrichment in Ba, Sr, Zr and LREE reported from the single geochemical analysis in 2019 (Couëslan, 2020). Three additional samples of titanite-bearing hornblende granite and one sample of the ilmenite-bearing quartz monzodiorite were collected for further study.

Sulphide- and titanite-rich calcsilicate

Calcsilicate is common from the top of the Precambrian to 254.5 m, where it is diffusely interlayered with hornblende gneiss and is interpreted to represent carbonate and/or epidote alteration within mafic igneous rocks (possibly basalt; Couëslan, 2020). The calcsilicate is plagioclase rich, with 30–40% clinopyroxene, and contains trace amounts of carbonate, magnetite, pyrrhotite, titanite and local garnet (Figure GS2020-3-3a). Several examples of anomalously sulphide-rich (up to 15%) and titanite-rich (up to 7%) calcsilicate were identified in the drillcore. Varieties can be similar to the typical calcsilicate described above, but with up to 3% magnetite, 3% sulphide and 7% titanite (Figure GS2020-3-4b), or they can be enriched in epidote, titanite and sulphide with minor carbonate (Figure GS2020-3-4c). Locally, the enriched calcsilicate appears to overprint the fabric of the country rock (Figure GS2020-3-4d); however, it also occurs as xenoliths with a well-developed fabric hosted within the hornblende granite (Figure GS2020-3-4b). There are also rare examples of discordant vein-like calcsilicate (Figure GS2020-3-4e). The wide textural and mineralogical variability likely indicates multiple ages and origins for the sulphide- and titanite-rich calcsilicate. Four samples of sulphide- and titanite-rich calcsilicate were collected for thin-section and geochemical analysis.

Bleached rock

A single zone of bleached rock, approximately 40 cm thick, occurs within the multicomponent gneiss interval. It is light grey and moderately magnetic with sharp contacts that crosscut fabrics and structures (including xenoliths) in the host tonalite (Figure GS2020-3-4f). The rock consists dominantly

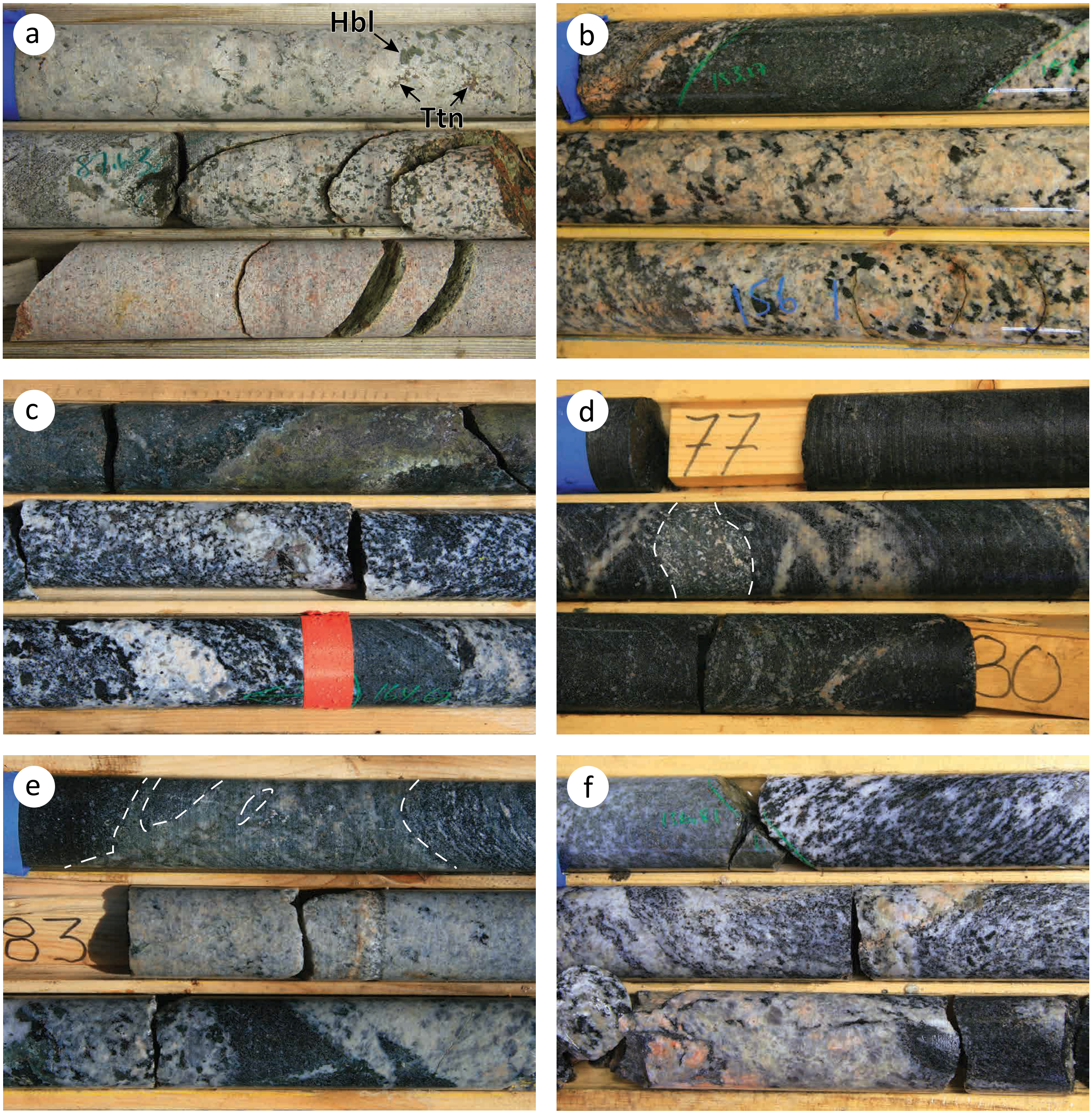


Figure GS2020-3-4: *Drillcore images of rocks from drillhole HZ-19-1:* ***a)*** *hornblende granite (top two rows) and aplite (bottom row; 86.0 m);* ***b)*** *xenolith of foliated sulphide- and titanite-rich calcsilicate (top row) contained within hornblende granite (bottom two rows; 153.1 m);* ***c)*** *titanite-, sulphide- and epidote-rich calcsilicate (top row; 167.7 m);* ***d)*** *titanite-rich calcsilicate that overprinted the fabric of the country rock (middle row, dashed outline; 77.0 m);* ***e)*** *discordant, vein-like calcsilicate in hornblende gneiss (top row, dashed outline), the hornblende gneiss intruded by hornblende granite (bottom two rows; 81.6 m);* ***f)*** *bleached/metasomatized rock that overprinted tonalite (top row, left of green line; 136.7 m). Abbreviations: Hbl, hornblende; Ttn, titanite.*

of quartz and feldspar with 10–12% pale green amphibole and minor carbonate, titanite and sulphide. A sample of the bleached rock was collected for thin-section and geochemical analysis.

Economic considerations

Alkaline-affinity magmatism and A-type granites can both be associated with rare-metal mineralization. Zirconium, Nb, Y, REE and F mineralization can be found associated with A-type granites (Dall'Agnol and Rämö, 2009). Alkaline-affinity igneous complexes in the THO of Manitoba have been explored for U, REE and P, and the Eden Lake complex is host to postorogenic carbonatite intrusions (Chakhmouradian et al., 2008). Post-orogenic carbonatites are a major source for the global supply of REE (e.g., Hou et al., 2009). Most of these elements are considered critical materials/minerals by the U.S. Department of the Interior (Schulz et al., 2017). Further work is required to determine the affinity of the hornblende granite and the significance of the sulphide- and titanite-rich calcsilicate and bleached rock. If the hornblende granite is related to either A-type granite magmatism or alkaline-affinity magmatism, it could indicate potential for these deposit types in the area, especially if a larger igneous complex or dike swarm is found to be present.

Acknowledgments

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GS2020-4

Detrital zircon and whole-rock lithogeochemical analyses of poorly exposed and sub-Phanerozoic metasedimentary basement rocks in the Watts, Mitishto and Hargrave rivers area, north-central Manitoba (parts of NTS 63J5, 6, 11–14)

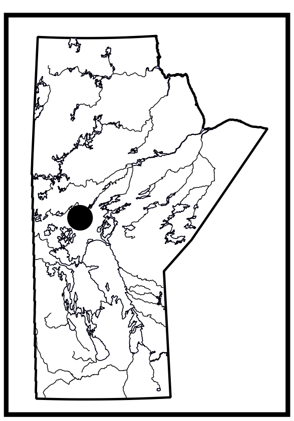
by K.D. Reid

In Brief:

- Metasedimentary rocks with Archean provenance and Ospwagan-like geochemistry occur west of the traditional Thompson nickel belt
- A significant portion of the metasedimentary rocks has geochemistry similar to the Burntwood group
- Detrital zircons in metasedimentary rocks have, depending on the sample, either a dominant Paleoproterozoic or Archean provenance

Citation:

Reid, K.D. 2020: Detrital zircon and whole-rock lithogeochemical analyses of poorly exposed and sub-Phanerozoic metasedimentary basement rocks in the Watts, Mitishto and Hargrave rivers area, north-central Manitoba (parts of NTS 63J5, 6, 11–14); *in* Report of Activities 2020, Manitoba Agriculture and Resource Development, Manitoba Geological Survey, p. 21–30.



Summary

The area southeast of Snow Lake and west of Highway 6, occupied by the Watts, Mitishto and Hargrave rivers, represents a complex structural confluence along the Superior boundary zone where rocks of the Paleoproterozoic Flin Flon and Kisseynew domains are juxtaposed and interleaved with Paleoproterozoic and Archean rocks of the Superior province margin. Poor exposure or cover by Phanerozoic rocks limits direct methods of data collection of Precambrian rocks to the examination and sampling of drillcore. Presented here is a geochemical comparison of metasedimentary rocks from select drillcore normalized to the average pelite from the P2 member of the Pipe formation of the Ospwagan group. This data is complemented by detrital zircon analyses on two samples from these drillcore, providing additional constrains on the provenance of the metasedimentary rocks.

Introduction

The Manitoba Geological Survey (MGS) continued a multiyear geological mapping project focused on parts of the Paleoproterozoic Flin Flon and Kisseynew domains that extend beneath Phanerozoic rocks (Figure GS2020-4-1). This project was initiated in 2009–2010 and continued in 2017 after a hiatus. The objective of the project is to enhance the geological understanding of the poorly exposed and sub-Phanerozoic Flin Flon and Kisseynew domain rocks (e.g., Simard et al., 2010; Reid, 2017). Geological knowledge of this region is limited, but exploration drilling for volcanogenic massive-sulphide (VMS) and magmatic nickel deposits has indicated that many of the tectonostratigraphic elements that make the exposed rocks economically significant extend under the Phanerozoic rocks.

Discussed in this report are the results of whole-rock lithogeochemical and detrital zircon analyses of metasedimentary rocks from drillcore in the Watts, Mitishto and Hargrave rivers area (southeast of Snow Lake and west of Highway 6) that was relogged and sampled during the 2017 and 2018 field seasons (Reid, 2017, 2018). These metasedimentary rocks have variable composition (impure quartzite, psammite, psammopelite, pelite) and are interpreted to represent a significant portion of the rocks located in the study area.

Previous work

Previous work in the study area includes regional mapping, with integrated aeromagnetic, gravity and drillcore data, of the sub-Phanerozoic portion of the Flin Flon and Kisseynew domains by the Geological Survey of Canada (Leclair et al., 1997; NATMAP Shield Margin Project Working Group, 1998). This work resulted in the recognition of several lithotectonic subdomains (Figure GS2020-4-2), some of which occur exclusively under the Phanerozoic cover (e.g., Cumberland domain, Namew gneiss complex, Cormorant batholith) and others that are both exposed and under Phanerozoic cover (e.g., Athapapuskow domain/Elbow-Athapapuskow assemblage, Clearwater domain/Snow Lake assemblage, eastern Kisseynew domain and Superior boundary zone). Macek et al. (2006) reviewed drillcore from along the Superior boundary zone, from Hargrave River south-southwest approximately 150 km to Cedar Lake, providing new information on the distribution and structure of the Paleoproterozoic sedimentary and volcanic cover succession (Ospwagan group) on the northwestern margin of the Archean Superior province. Macek et al. (2006) approximated the contact between apparent Burntwood group turbidites (broad aeromagnetic low) and undifferentiated Archean basement (aeromagnetic highs) of the Superior province.

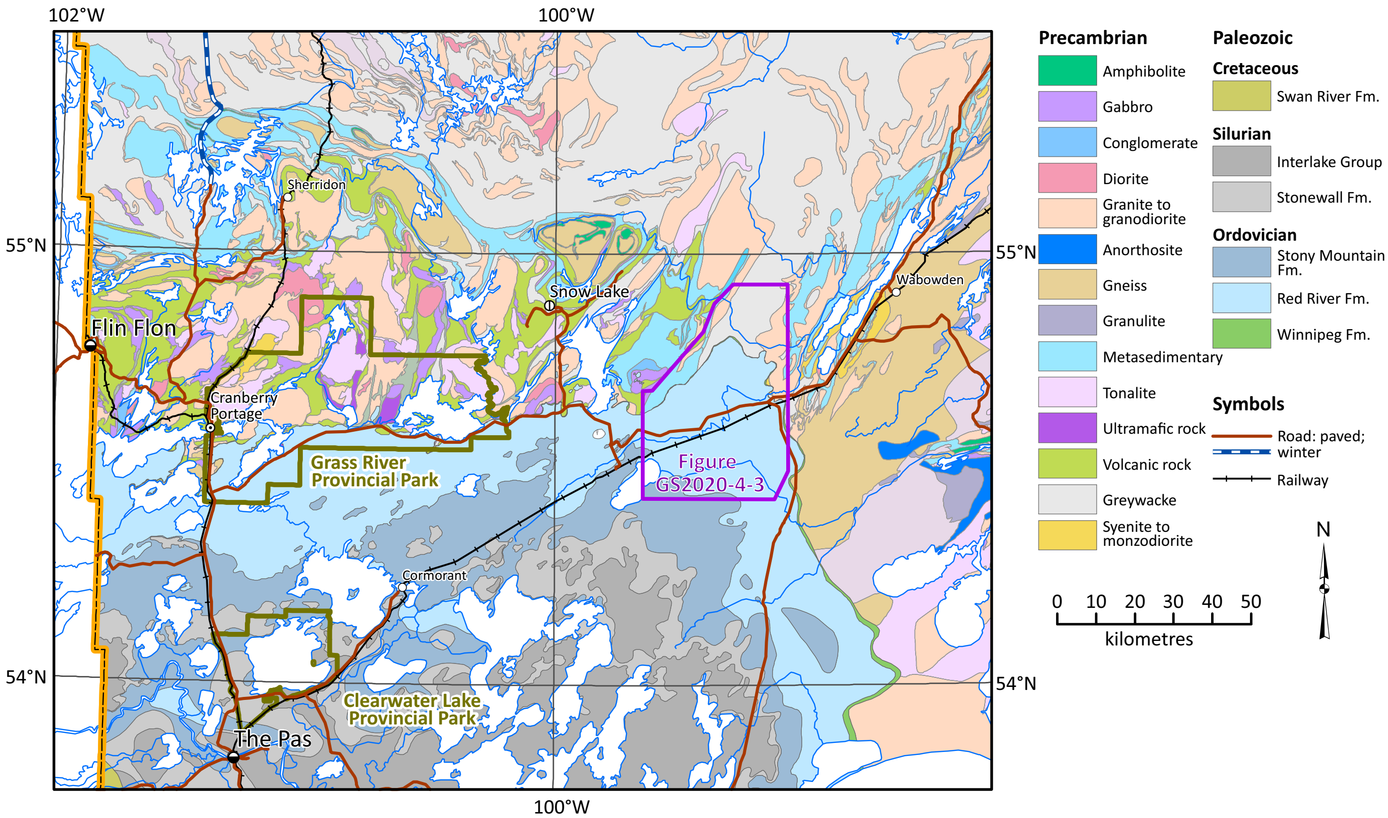


Figure GS2020-4-1: *General bedrock geology of the Flin Flon and Snow Lake region, north-central Manitoba (modified from Reid, 2018).*

Simard and McGregor (2009) initiated data compilation to aid in mapping the sub-Phanerozoic portion of the Flin Flon and Kisseynew domains. The authors' objectives were to better characterize the various geophysical subdomains outlined by Leclair et al. (1997) using existing and new geochronological, isotopic and geochemical data, which aided a comparison between the sub-Phanerozoic rocks and the tectonostratigraphic assemblages of the exposed Flin Flon domain. Simard et al. (2010) completed detailed work on eight poorly understood VMS deposits from the Clearwater and eastern Kisseynew domains showing that they formed in different lithotectonic environments. Deposits in the Clearwater domain (Moose, Limestone, Sylvia, Kofman) are hosted in bimodal tholeiitic to transitional oceanic-arc rocks at 'lower metamorphic grade', whereas those of the eastern Kisseynew domain (Watts River, Fenton, Harmin, Talbot) are hosted by volcanic and sedimentary rocks formed in a rifted arc and/or back-arc environment and metamorphosed at relatively 'high metamorphic grade'. More recently, Reid (2017, 2018) has conducted regional drillcore review coupled with aeromagnetic interpretation to subdivide the Watts, Mitishto and Hargrave rivers area (e.g. Figure GS2020-4-3).

Whole-rock lithogeochemistry of metasedimentary drillcore samples

Detailed lithostratigraphy for rocks along the Superior boundary zone from Setting Lake to Thompson has been described by several authors (e.g., Bleeker, 1990; Zwanzig and Böhm, 2002). More recently, Zwanzig et al. (2007) characterized the stratigraphy of the Ospwagan group—the cover sequence to the Thompson nickel belt basement—by normalizing whole-rock lithogeochemistry of all stratigraphic formations and members to the average pelite of the P2 member of the Pipe formation (P2 pelite). Normalized samples were plotted on extended-element spider diagrams, which include rare-earth elements (REEs), high-field-strength elements (HFSEs: Nb, Ti, U, Th) and some large-ion lithophile elements (LILEs: Rb, Ba, Sr, K). The results are useful when attempting to interpret the lithostratigraphic setting of highly metamorphosed rocks in drillcore. For further discussion and a more in-depth review regarding geochemical characterization of sedimentary rocks along the northwestern flank of the Superior province, the reader is referred to Zwanzig et al. (2007).

Adopting the method of Zwanzig et al. (2007), individual analyses of metasedimentary rocks in the study area were normalized to the average P2 pelite. From this data, the 75th percentile (upper dash line), median (middle dash line) and 25th percentile (lower dash line) were calculated for sample groups and then plotted (Figure GS2020-4-4). Median values of stratigraphic components of the Ospwagan, Burntwood and Grass River groups are plotted on Figure GS2020-4-4a–c (data from Zwanzig et al., 2008) so the reader can make a comparison to the unclassified metasedimentary rocks in drillcore from the study area. The drillcore submitted for geochemical analysis

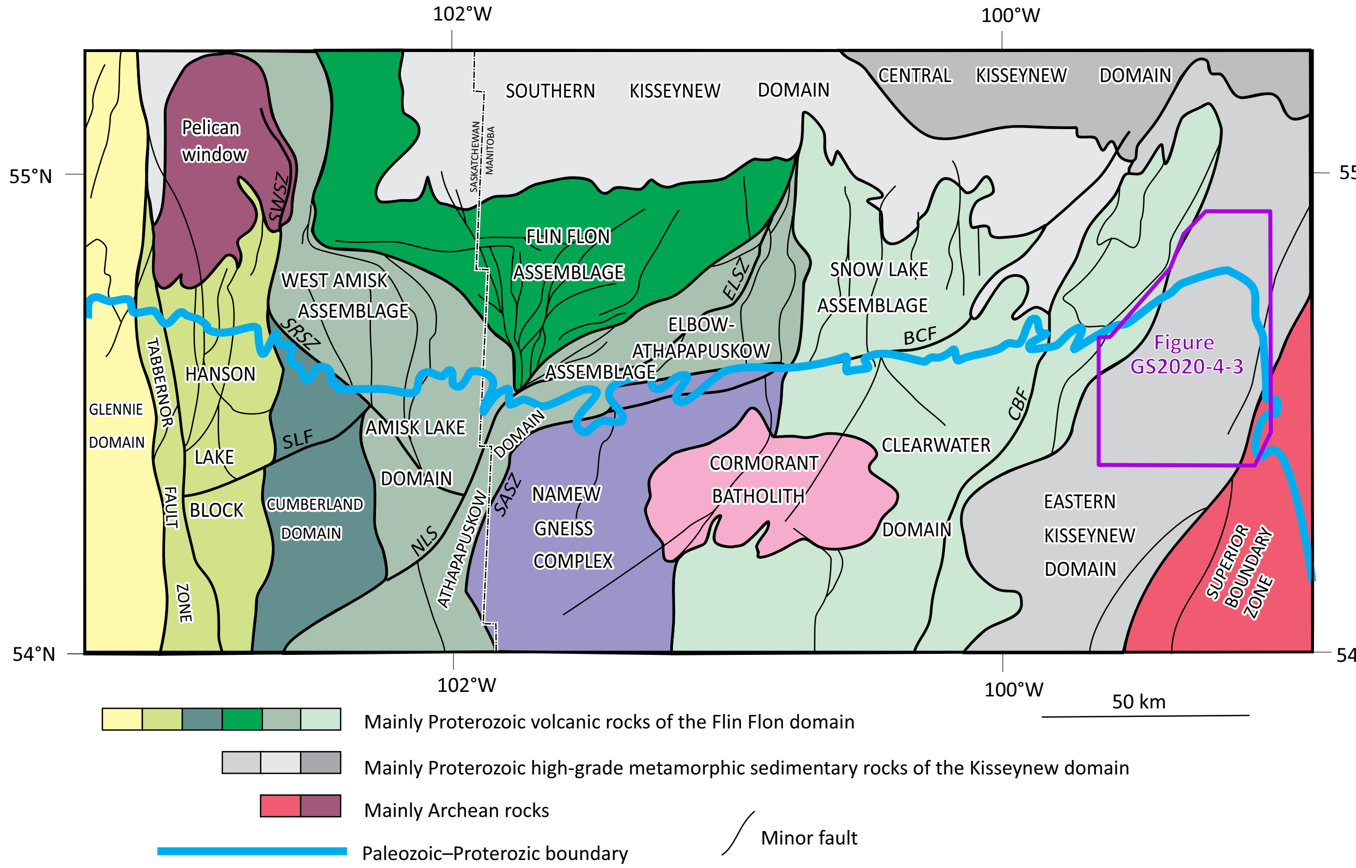


***Figure GS2020-4-2:** Interpreted lithotectonic subdomains of the Flin Flon and Kisseynew domains in west-central Manitoba and east-central Saskatchewan (after NATMAP Shield Margin Project Working Group, 1998). Abbreviations of major faults and shear zones: BCF, Berry Creek fault; CBF, Crowduck Bay fault; ELSZ, Elbow Lake shear zone; NLS, Namew Lake structure; SASZ, South Athapapuskow shear zone; SLF, Suggi Lake fault; SRSZ, Spruce Rapids shear zone; SWSZ, Sturgeon Weir shear zone. The heavy blue line is the contact between the exposed Precambrian rocks to the north and Phanerozoic-covered Precambrian rocks to the south.*

are from Hudbay Minerals Inc. exploration programs between 2000 and 2018. More details regarding sampling and analytical methods are being prepared as a Data Repository Item (K.D. Reid, work in progress).

Lithogeochemistry of drillcore samples from Zwanzig et al. (2008)

Ospwagan group

Figure GS2020-4-4a shows that iron formation and semipelite of the Pipe formation, P3 member (yellow), and calcareous semipelite and marlstone of the Thompson formation (T, purple) have median profiles that are relatively flat or gently negatively sloped and have slightly lower concentrations of heavy rare-earth elements (HREEs) compared to average P2 pelite. Silicate- and sulphide-facies iron formation of the Pipe formation, P1 member (Figure GS2020-4-4a, orange), has a similar profile to that of P2 pelite with the exception of lower HREE concentrations. The M1 member of the Manasan formation, composed of impure quartzite, quartzite and minor conglomerate with minor pelite, has a median profile that is irregular, has a somewhat gentle positive slope and is generally less enriched than P2 pelite except for elevated concentrations of K and P (Figure GS2020-4-4b, red). Manasan formation M2 member semipelite has very similar element concentrations compared to P2 pelite (Figure GS2020-4-4b, grey). Setting Lake formation psammite and pelite (Figure GS2020-4-4b, S, light green) have similar concentrations of LILEs to P2 pelite but have lower HREE concentrations.

Burntwood and Grass River groups

Figure GS2020-4-4c shows that Burntwood group greywacke (blue) and Grass River group sandstone and conglomerate (green) have similar median profiles when normalized to P2 pelite. Both have a consistent gentle positive slope from LILEs to HREEs with distinctly lower concentrations of Rb, K and Zr and higher concentrations of U, Sr and P relative to P2 pelite.

Lithogeochemistry of drillcore samples from the study area

Impure quartzite and pelite

Drillholes KUS318 and KUS342 are representative of an area of narrow northeast-trending magnetic highs and lows

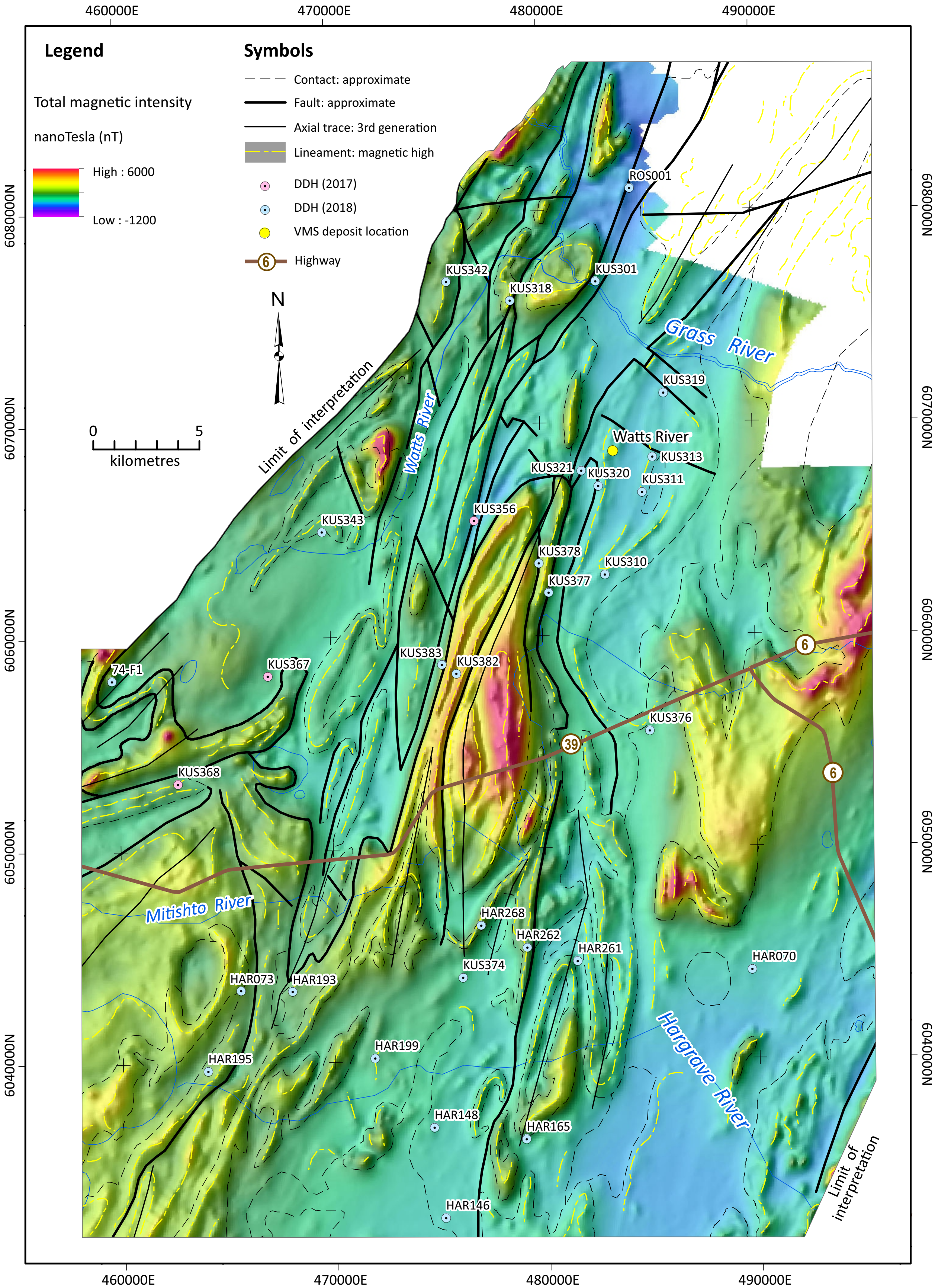


Figure GS2020-4-3: *Detailed aeromagnetic map (after Keating et al., 2012) for the study area showing interpreted geological contacts, faults and drillhole locations (modified after Reid, 2018, Figure GS2018-4-2). UTM Zone 14, NAD83. Abbreviations: DDH, diamond drillhole; VMS, volcanogenic massive-sulphide.*

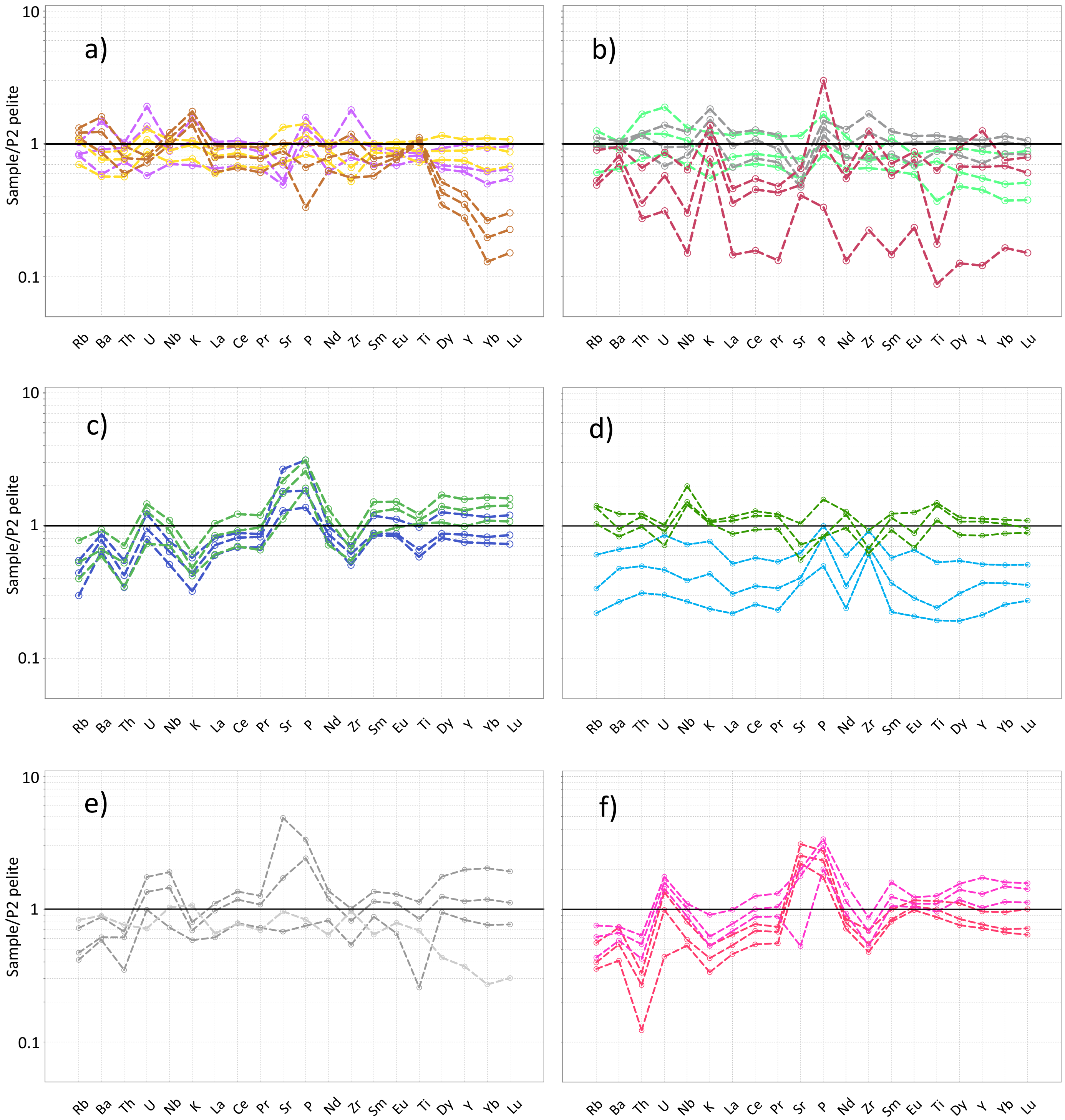


Figure GS2020-4-4: *Extended-element diagrams showing the 75th percentile (upper dash line), median (middle dash line) and 25th percentile (lower dash line) of trace-element whole-rock compositions of metasedimentary rocks from the study area normalized to the average pelite of the P2 member of the Pipe formation (P2 pelite, black line) of Zwanzig et al. (2007):* ***a)*** *Pipe formation (P1 member, orange, n=2; P3 member, yellow, n=9) and Thompson formation (T, purple, n=5);* ***b)*** *Manasan formation (M1 member, red, n=7; M2 member, grey, n=7) and Setting Lake formation (S, light green, n=12);* ***c)*** *Burntwood group (blue, n=14) and Grass River group (green, n=12);* ***d)*** *psammite and impure quartzite (drillcore KUS318 and KUS342, light blue, n=8) and psammopelite to pelite (drillcore KUS318 and KUS342, green, n=4);* ***e)*** *psammite and quartzofeldspathic gneiss (drillcore KUS378, dark grey, n=4; drillcore HAR195, light grey, n=1);* ***f)*** *psammopelite and pelite (drillcore KUS343, KUS356 and KUS367, magenta, n=10; drillcore KUS376 and HAR070, red, n=13). The data in* ***a)–c)*** *are from Zwanzig et al. (2008).*

near the Watts River in the northwestern portion of the study area (Figure GS2020-4-3). Reid (2018) described these rock units as being mainly psammite and conglomerate but further review of the geochemical composition indicates these drillcore contain impure quartzite and psammite interleaved with psammopelite to pelite (K.D. Reid, work in progress). Impure quartzite and pelite in close association is not a stratigraphic association commonly observed in the Kisseynew domain (Zwanzig and Bailes, 2010). Normalizing the metasedimentary rocks of KUS318 and KUS342 to P2 pelite (Figure GS2020-4-4d), it is apparent that the median composition of the psammopelite to pelite is not much different than that of the Pipe, Thompson and Manasan formations (Figure GS2020-4-4a, b). Psammite and impure quartzite (Figure GS2020-4-4d, light blue) have lower concentrations of all elements relative to P2 pelite, but in this respect are similar to the subarkosic sandstone of the M2 member of the Manasan formation (Figure GS2020-4-4b, grey).

Drillhole KUS378 penetrates rocks associated with an ovoid magnetic high in the middle of the study area (Figure GS2020-4-3) and contains psammite to psammopelite, which display layering at the centimetre to decimetre scale. These rocks have a gently positive slope and elevated U, Nb, Sr, P and HREEs relative to P2 pelite (Figure GS2020-4-4e, dark grey), this pattern most closely resembles that of the Grass River group (Figure GS2020-4-4c, green).

Near the Hargrave River, drillhole HAR195 intersects highly strained felsic gneiss that is interpreted to represent psammite (Reid, 2018). It has a relatively flat profile with similar element concentrations to that of P2 pelite with the exception of the HREEs, which are depleted (Figure GS2020-4-4e, light grey). Overall it is similar to the P1 member of the Pipe formation (Figure GS2020-4-4a, orange) suggesting it may be related to Ospwagan group stratigraphy.

Psammopelite and minor pelite

Drillholes KUS343 and KUS367 occur in a broad aeromagnetic low in the western portion of the study area whereas drillhole KUS356 occurs in a narrow northeast-trending aeromagnetic low to the east (Figure GS2020-4-3). These drillcore are composed of gradational rock types ranging from psammopelite to pelite with variable amounts of biotite and garnet and minor sillimanite present in the more pelitic intervals (Reid, 2018). Metasedimentary rocks in drillholes KUS376 and HAR070, in the eastern part of the study area, are similar to the psammopelite and pelite described in the western half of the study area (KUS343, KUS356, KUS367) but have increased quartzofeldspathic neosome and biotite-garnet–rich melasome, with sillimanite being rare or absent. The median compositions from samples from the western and eastern side of the study area both have consistent positive slopes with generally elevated U, Sr and P and reduced Th, K and Zr compared to P2 pelite (Figure GS2020-4-4f). However, psammopelite and pelite from the eastern study area (Figure GS2020-4-4f, red) show slightly lower concentrations of LILEs, HFSEs and REEs than corresponding rocks in the west (Figure GS2020-4-4f, magenta). These psammopelite and pelite have similar geochemical profiles (Figure GS2020-4-4f) to average Burntwood and Grass River groups (Figure GS2020-4-4c) along the northwestern flank of the Superior province (Zwanzig et al., 2007) suggesting these rocks may have a genetic link to the broader Burntwood group in the Kisseynew domain.

Detrital zircons from metasedimentary rocks in drillcore

Metasedimentary rocks from drillcore HAR070 and KUS378 were processed for detrital zircon extraction; Figure GS2020-4-3 shows the location of the drillholes. Sampling targeted the paleosome, avoiding the neosome (both leucosome and melanosome) material. Sample information, analytical methods and raw data are summarized in Data Repository Item DRI2020026 (Reid, 2020)[1]. Detrital zircon data presented in this report were plotted with P. Vermeesch's DensityPlotter software using the kernel density estimator (KDE), which is similar in appearance to the probability density plot (PDP). The KDE was selected because it uses a more solid theoretical foundation and is statistically more robust than the PDP (Vermeesch, 2012). This study used Epanechnikov kernel with an adaptive bandwidth based on the equation of Botev et al. (2010) and a bin width of 10 Ma for the histogram. Only data that are greater than 95% concordant or less than 5% discordant were used to produce the kernel density estimate.

Drillcore HAR070

Figure GS2020-4-5a shows a typical garnet-biotite psammopelite sampled from drillcore HAR070. Zircon analyses plotted on a concordia diagram (Figure GS2020-4-6a) show a significant distribution, whereas the kernel density estimate (Figure GS2020-4-6b) shows that the majority of the 150 zircon analyzed (~75%) are between 1.91 and 1.79 Ga, broadly corresponding with previously published ages for juvenile oceanic-arc volcano-sedimentary rocks of the Paleoproterozoic Flin Flon domain (e.g., David et al., 1996; Syme et al., 1999). Discrete peaks around 1852 and 1819 Ma likely record two known regional processes. The younger age peak around 1819 Ma corresponds to peak thermal metamorphism in the region (e.g., Gordon et al., 1990; Kraus and Williams, 1999). The second peak around 1852 Ma records the age of the dominant

[1] MGS Data Repository Item DRI2020026 containing the data or other information sources used to compile this report is available online to download free of charge at https://www.manitoba.ca/iem/info/library/downloads/index.html, or on request from minesinfo@gov.mb.ca, or by contacting the Resource Centre, Manitoba Agriculture and Resource Development, 360–1395 Ellice Avenue, Winnipeg, MB R3G 3P2, Canada.

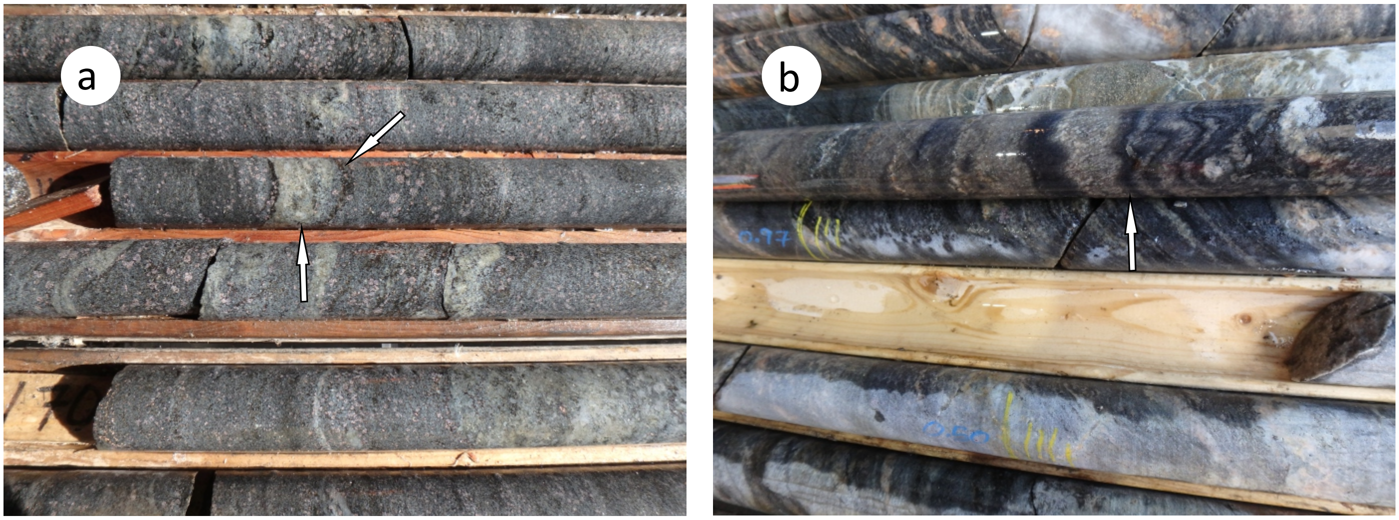


***Figure GS2020-4-5:** Photographs of the different rock types from drillcore sampled for detrital zircon dating: **a)** garnet-biotite psammopelite with leucosome (lower arrow) and melanosome (upper arrow), drillhole HAR070; **b)** psammite showing primary sedimentary layering (arrow), drillhole KUS378. Drillcore is NQ and has a diameter of 47.6 mm.*

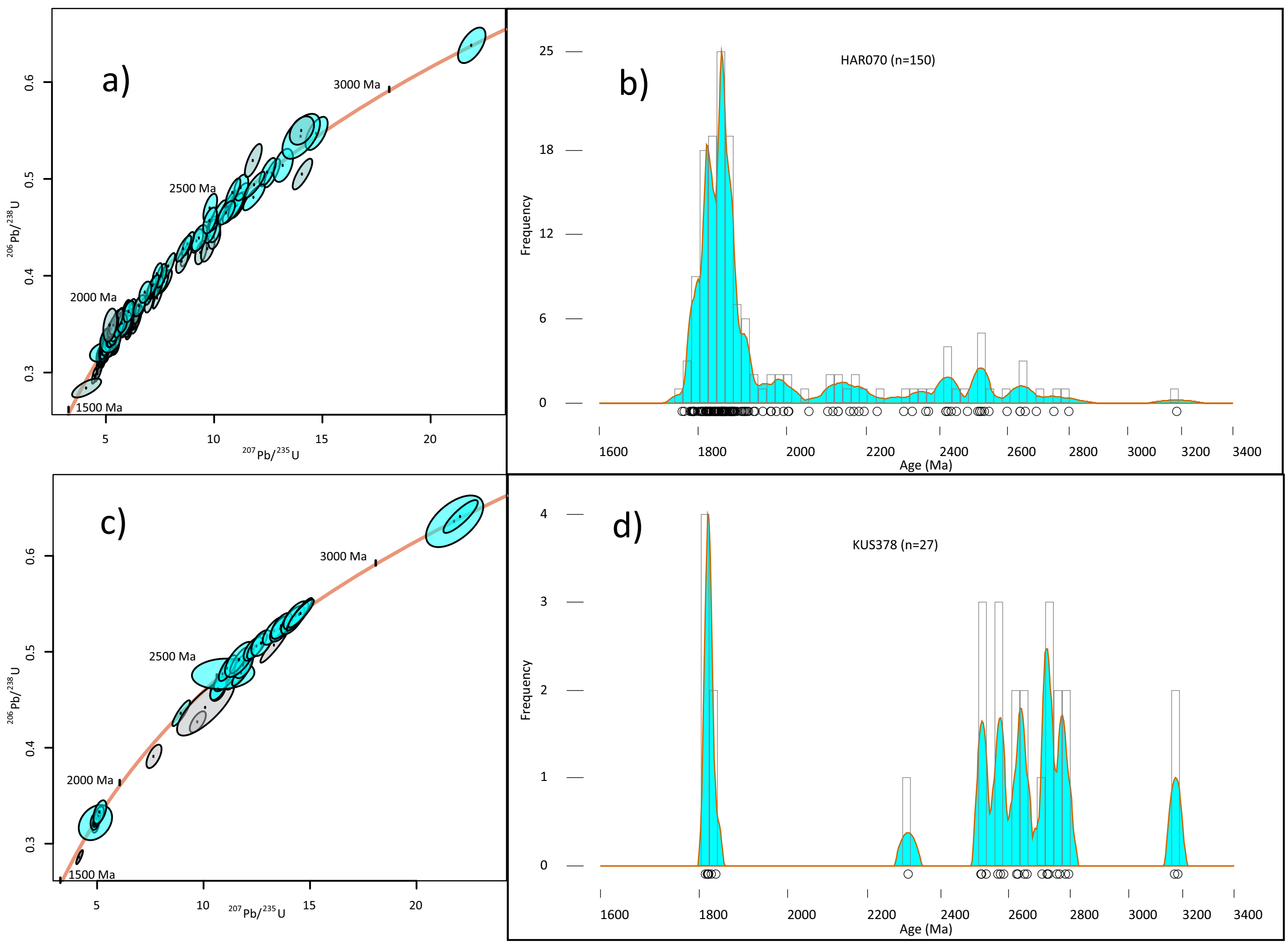


***Figure GS2020-4-6:** Detrital zircon U-Pb age results: **a)** concordia diagram for zircons in the sample from drillcore HAR070; **b)** kernel density estimate for zircons in the sample from drillcore HAR070; **c)** concordia diagram for zircons in the sample from drillcore KUS378; **d)** kernel density estimate for zircons in the sample from drillcore KUS378.*

detrital input and corresponds very closely with the youngest detrital zircons in Burntwood group turbidites, 1856 Ma at Wekusko Lake and 1854 Ma at File Lake (David et al., 1996), and is comparable to other estimates of sedimentation dates for Burntwood group rocks (e.g., Machado and Zwanzig, 1995).

Minor clusters of ages occur around 2.54–2.50, 2.45–2.41, 2.20–2.10 and 2.00–1.96 Ga, and a single grain has an age of ~3.18 Ga (Figure GS2020-4-6b). The older ~2.70–2.10 Ga zircons in drillcore HAR070 overlap with the older detrital zircons observed at File Lake and inherited older Archean zircon ages in Snow Lake arc volcanic rocks (David et al., 1996), whereas the ~3.18 Ga age is correlative to igneous ages in the Assean Lake block to the north (Böhm et al., 1999).

Drillcore KUS378

Figure GS2020-4-5b shows psammite with primary sedimentary layering in drillcore KUS378. Zircons in the sample from drillcore KUS378 yielded both Paleoproterozoic and Neoarchean ages and a few older Archean ages (Figure GS2020-4-6c). The kernel density estimate data (n=27) show a discrete peak centred around 1818 Ma as well as peaks around 2.77, 2.72, 2.64, 2.57 and 2.52 Ga, a range from 2.79 to 2.52 Ga (Figure GS2020-4-6d). Only three zircons fall outside of this range; one dated around 2.31 Ga and two with ages around 3.18 and 3.17 Ga. The sample lacks zircons with ages before 1.84 Ga, typical of the Flin Flon domain (1.92–1.83 Ga; Syme et al., 1999), except for the discrete peak at 1818 Ma, which is interpreted to represent metamorphic overprint (e.g., Gordon et al., 1990; Kraus and Williams, 1999). Considering that rocks at drillholes HAR070 and KUS378 have a close spatial association it would be expected that they have undergone a similar peak metamorphism around 1819 Ma. The Neoarchean component of drillcore KUS378 has detrital ages that correspond with the tectonometamorphic history of the adjacent Superior province, making it the most likely source of the sediments. This includes an older >3.0 Ga basement, ~2.8–2.7 Ga volcanic and plutonic rocks, and ~2.70–2.64 Ga metamorphism (e.g., Mezger et al., 1990; Böhm et al., 1999; Heaman et al., 2011), however, the <2.64 Ga record in drillcore KUS378 is problematic and not generally recognized as a common component of the Superior province. The 2.52 Ga component of drillcore KUS378 is comparable to 2.52–2.50 Ga tonalite that is structurally imbricated between 1.90–1.88 Ga oceanic rocks in the Northeast Arm shear zone (David and Syme, 1994), and is similar to ages that represent the Sask craton (Rayner et al., 2005). Therefore, it is possible that part of the provenance for this rock may include the Sask craton. Although not a reproducible age, assuming the ~2.31 Ga zircon is the youngest detrital grain, the maximum depositional age would be <2.31 Ga.

It is noteworthy that the detrital zircons in the psammite of drillcore KUS378 have similarities to detrital zircons in the Saw Lake protoquartzite approximately 25 km to the north-northwest (Bailes and Böhm, 2008). Excluding the single ~2.31 Ga zircon in drillcore KUS378, these samples have comparable youngest detrital zircons, 2.52 Ga in drillcore KUS378 versus 2.51 Ga in the Saw Lake protoquartzite (Bailes and Böhm, 2008), and both have age ranges from ~2.79 to 2.51 Ga.

Geological implications

Geochemical and detrital zircon data indicate that the Watts, Mitishto and Hargrave rivers area contains metasedimentary rocks related to both i) an Ospwagan group rift-related and passive margin sequence derived from the Archean Superior province and ii) Burntwood and Grass River groups greywacke, sandstone and conglomerate derived from Paleoproterozoic juvenile oceanic arcs. For example, drillcore KUS318 and KUS342 both contain impure quartzite and pelite in close association, which is not a stratigraphic association commonly observed in the Kisseynew domain (Zwanzig and Bailes, 2010), and have geochemistry that resembles Ospwagan group rocks found in the Thompson nickel belt more so than rocks of the Kisseynew domain (Figure GS2020-4-4d). Detrital zircon analyses of psammite in drillcore KUS378, which is associated with a large north-northeast trending ovoid magnetic high in the centre of the study area (Figure GS2020-4-3), contains metasedimentary rocks of only Archean provenance.

Aeromagnetic interpretation coupled with the drillhole observations and geochemistry suggest that metasedimentary rocks similar to those of the Burntwood group in the Kisseynew domain make up a significant portion of the study area (e.g., drillcore KUS343, KUS356, KUS367, KUS376, HAR070). The dominantly Paleoproterozoic detrital zircons (1.91–1.79 Ga; Figure GS2020-4-6b) from drillcore HAR070 corroborate this interpretation.

The observations indicate that metasedimentary rocks with Archean provenance occur tens of kilometres west of the traditional Superior province margin (Thompson nickel belt) and are surrounded by rocks with Burntwood group geochemical affinity. Similarities can be drawn to the northeastern Kisseynew domain where Ospwagan group–like rocks at Wuskwatim Lake, which have an Archean provenance, are surrounded by Burntwood group rocks of the Kisseynew domain approximately 60 km from the exposed Thompson nickel belt (Zwanzig et al., 2006; Rayner and Percival, 2007).

Economic considerations

The study area contains the Watts River VMS deposit, which has a NI 43-101 compliant inferred resource of 6.62 million tonnes grading 1.88% copper, 2.63% zinc, 0.66 g/t gold and 25.61 g/t silver using a 3.0% zinc cut-off (Carter, 2007). Currently, the extent of prospective VMS-hosting stratigraphy in the study area is not well understood. Satellite deposits of varying size should accompany a deposit of the size and grade of the Watts River, but to date no other deposits have been found in the immediate vicinity.

If metasedimentary rocks with Archean provenance and Ospwagan group–like geochemical characteristics are indeed related to the Ospwagan group of the Superior province margin, arguably there is heightened potential for nickel-copper deposits west of the traditionally documented Thompson nickel belt in the area of the Watts, Mitishto and Hargrave rivers.

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GS2020-5

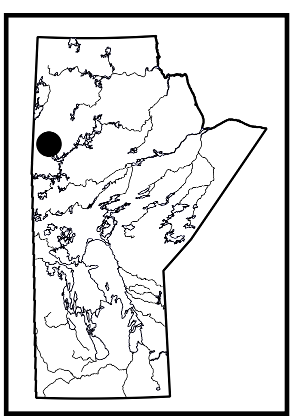
Preliminary results from bedrock mapping in the northern arm of Russell Lake, northwestern Manitoba (parts of NTS 64C5, 6)

by T. Martins and C.G. Couëslan

In Brief:

- Field work in the northern arm of Russell Lake is a continuous effort in updating bedrock geology and regional framework and interpretation of this part of the Kisseynew domain of the Trans-Hudson Orogen
- Bedrock outcrops of the area are dominated by the coeval sedimentary rocks of the Burntwood and Sickle groups, and mafic volcanic rocks
- Assay results from the 2019 field season reveal up to 3.31 wt. % total carbon in Burntwood group rocks, suggesting widespread economical potential for graphite in the Kisseynew domain

Citation:
Martins, T. and Couëslan, C.G. 2020: Preliminary results from bedrock mapping in the northern arm of Russell Lake, northwestern Manitoba (parts of NTS 64C5, 6); *in* Report of Activities 2020, Manitoba Agriculture and Resource Development, Manitoba Geological Survey, p. 31–40.



Summary

A multidisciplinary mapping project at Russell Lake was initiated by the Manitoba Geological Survey in the summer of 2019. Geological bedrock mapping at 1:20 000 scale continued in the 2020 field season, focusing on the northern arm of Russell Lake. Outcrops in the northern arm of Russell Lake are dominated by the coeval sedimentary rocks of the Burntwood and Sickle groups, as well as volcanic rocks and granodiorite intrusive bodies. Overall, these rock types are a continuation of the stratigraphy defined in the south basin of Russell Lake; however, there are distinct differences amongst the units. The mapped rock units were sampled for lithogeochemical, petrographic, metamorphic, isotopic and geochronological studies, and for comparison with the results from the previous field season. Graphite contents of Burntwood sedimentary rocks suggest widespread economic potential for this commodity in the study area and the Kisseynew domain at large. Furthermore, observations from this year's field season suggest that graphite is also present within a quartzite unit spatially associated with volcanic rocks.

Introduction

Bedrock mapping was undertaken by the Manitoba Geological Survey (MGS) in the northern arm of Russell Lake during June and July of 2020 as a follow-up to work by Martins and Couëslan (2019a, b). Preliminary results from bedrock mapping of the 2020 field season are presented here and on the accompanying map PMAP2020-1 (Martins and Couëslan, 2020a).

Outcrops are less abundant in the northern arm of Russell Lake than in the south; this is especially true for the north shoreline, where esker deposits and boulders dominate. Steep rock faces, high water levels and often heavy and dark lichen cover hindered outcrop observations during the 2020 fieldwork. A magnetic anomaly map of Canada (Miles and Oneschuk, 2016) was used to help trace rock units. The preliminary maps of Baldwin (1974) and Zwanzig and Wielezynski (1975b) were used to trace units in areas that were inaccessible.

The main objectives of bedrock mapping for the 2020 field season were to

1) continue to update the bedrock geology to produce a seamless geological map of the Russell Lake area;
2) continue with lithogeochemical, isotopic, metamorphic and geochronology studies;
3) contribute to updating the regional framework and tectonic interpretation by taking into account recent work in the Trans-Hudson orogen (THO), particularly in the Granville Lake area (e.g., Zwanzig, 2019) of the Kisseynew domain (KD) north flank; and
4) assess the economic potential of the KD, especially graphite occurrences reported by previous authors (e.g., Lenton, 1981), in light of the current market trends and growing interest in this commodity.

Rock descriptions and mineral estimates in this report are based on outcrop observations. Further studies focusing on metamorphic, tectonic and stratigraphic interpretations of the Russell–McCallum lakes area are ongoing. All rocks in the study area were metamorphosed to at least upper-amphibolite–facies conditions (Lenton, 1981; Martins and Couëslan, 2019b); however, for the sake of brevity, the 'meta' prefix has been omitted from rock names. Where possible, protolith interpretation was used in the naming of rock units.

Previous work

The Russell–McCallum lakes area was previously mapped by Downie (1936) of the Geological Survey of Canada (GSC) at a scale of 1:253 440. Later, geological mapping by Hunter (1953) extended the regional coverage into McKnight Lake at a scale of 1:126 720. The MGS mapped the area in the 1970s, Russell Lake by McRitchie (1975a, b) at a scale of 1:126 720 and the adjoining areas by

Baldwin (1974) and Zwanzig and Wielezynski (1975a, b) at a scale of 1:126 720 and Pollock (1966) at a scale of 1:63 360. The area to the west of Russell–McCallum lakes was mapped by Gilboy (1976) at a scale of 1:100 000. Lenton (1981) mapped the area extending from the Russell–McCallum lakes area to McKnight Lake at a scale of 1:50 000. In 2019, the MGS initiated a multidisciplinary geological mapping project in the Russell–McCallum lakes area. Preliminary results of bedrock mapping can be found in Martins and Couëslan (2019a, b, 2020a, b), and results from surficial mapping in Hodder (2019, 2020).

The Russell Lake area was a target for economic studies focused on base-metal mineralization along the contact zone between rocks of the Burntwood and Sickle groups, the two major stratigraphic units of the area (Baldwin, 1976, 1980). There are records of base-metal exploration work in the area from 1954 until 1983 (e.g., Assessment Files 91616, 93803, Manitoba Agriculture and Resource Development, Winnipeg). Airborne electromagnetic surveys located a number of conductors that were commonly followed up by diamond-drilling. Unfortunately, base- and precious-metal assay results (e.g., Ni, Au, Ag, Cu) were not promising and led to abandonment of the claims. However, significant graphite mineralization was reported in the majority of drillholes (e.g., Assessment Files 92387, 93001, 93804), including Assessment File 90985, submitted by Hudson Bay Exploration and Development Company Limited. The company drilled six holes in 1962 and reported up to 2.2 m (7.3 feet) of near-solid to solid graphite, pyrite and pyrrhotite, 1.9 m (6.2 feet) of well-mineralized graphite and 1.2 m (4.1 feet) of mineralized graphite.

Regional geology

The KD forms the large central part of the predominantly juvenile Paleoproterozoic internides, which make up the Reindeer zone of the Trans-Hudson orogen (THO) in Manitoba (Figure GS2020-5-1; Stauffer, 1984; Lewry and Collerson, 1990). The KD is dominated by metamorphosed greywacke and mudstone of the Burntwood group and arkose of the Sickle group. The provenance of the Burntwood group is interpreted to be

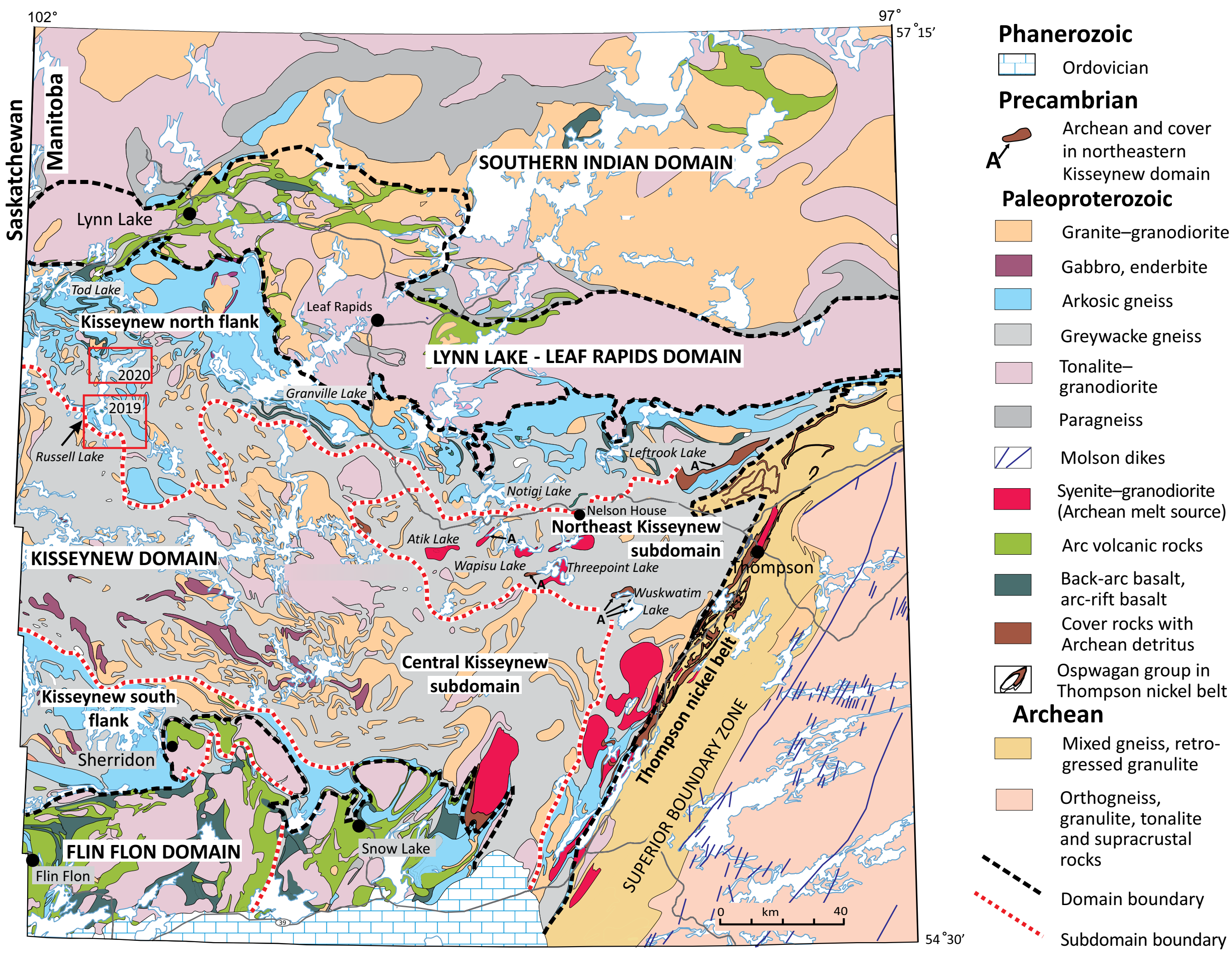


Figure GS2020-5-1: *Regional geology of the Trans-Hudson orogen in Manitoba, indicating the subdivision of the Kisseynew domain proposed by Zwanzig and Bailes (2010). Red rectangles outline the 2020 and 2019 study areas.*

the adjacent magmatic-arc terranes, with detritus from the arcs being deposited in coalescing turbidite fans (Bailes, 1980; Zwanzig, 1999). The turbidites were deformed and metamorphosed to amphibolite- and transitional granulite–facies, resulting in migmatization. Rocks from the Sickle group are typically metamorphosed arkosic units that are interpreted to have been deposited unconformably on the Lynn Lake arc massif (Zwanzig, 2008) and prograded over the Burntwood group during the onset of terminal continental collision. Both Burntwood and Sickle groups are intruded by granitoid rocks, including foliated granitoid bodies ranging from granite to tonalite and later pegmatite (e.g., Lenton, 1981; Zwanzig and Bailes, 2010; Zwanzig, 2019).

The geological setting of the KD is a matter of debate. Some authors (Ansdell, 2005; Corrigan et al., 2005, 2009) favour the interpretation of the KD as a back-arc basin to the Flin Flon volcanic arc that was filled during its opening. However, other authors (e.g., Zwanzig, 1999; Zwanzig and Bailes, 2010) favour an interpretation of a longer lived and dynamic evolution in which the present geographic distribution of rocks resulted from crustal-scale overturning and oroclinal bending during continental collision.

The Russell Lake area is located within the Kisseynew north flank, a subdivision of the KD introduced by Zwanzig and Bailes (2010; Figure GS2020-5-1). The Kisseynew north flank is dominated by Paleoproterozoic metasedimentary rocks of the Burntwood and Sickle groups, typically separated by the volcanosedimentary Granville complex, a composite, predominantly mafic assemblage that includes remnants of ocean floor. The Kisseynew north flank is bounded to the north by the Lynn Lake belt, to the east by the northeast Kisseynew subdomain and to the south by the central Kisseynew subdomain.

Bedrock geology of Russell Lake, northern arm

The majority of outcrops in the northern arm of the Russell lake area are dominated by sedimentary rocks of the Burntwood and Sickle groups, volcanic rocks and minor granodiorite bodies (Figure GS2020-5-2). Figure GS2020-5-3 represents an idealized stratigraphic column for the Russell Lake area presented by Martins and Couëslan (2019b). The Burntwood and Sickle groups are interpreted to be coeval (e.g., Zwanzig and Bailes, 2010); therefore, the succession of units is not to be viewed as a true chronostratigraphic sequence.

Mafic volcanic rocks and associated sediments (unit 1a–d)

Massive basalt (unit 1a)

Massive basalt (unit 1a) is dark green-grey, medium to coarse grained and foliated, with massive layering <2 m thick. Local, discontinuous and heterogeneous bands (<10 cm wide) may represent flow breccia. Local, discontinuous green layers could be the result of calcsilicate alteration (Figure GS2020-5-4a) or represent strongly attenuated pillowed basalt. The composition of the massive basalt is variable but is typically 60–70% amphibole, 20–30% plagioclase and 5–10% biotite, with trace amounts of pyrite and chalcopyrite, and rare magnetite. Local layers contain up to 10% garnet, which can be partially or completely pseudomorphously replaced by plagioclase. Local gossanous zones or layers up to 2 m wide occur within the basalt. The gossanous layers can be associated with zones of carbonate alteration containing variable amounts of carbonate, quartz, very dark titanite or spinel, diopside and plagioclase, or be spatially associated with quartzite (unit 1c) or diopside gneiss (unit 1d).

Pillowed basalt (unit 1b)

Pillowed basalt (unit 1b) was identified with confidence in a single outcrop in the northern arm of Russell Lake; however, it is more common in the southern basin. This unit is foliated, nonmagnetic and medium to coarse grained, with light grey-green weathered and dark green fresh surfaces. The groundmass is plagioclase rich, with 50–60% hornblende, up to 5% garnet and trace to 1% pyrite and chalcopyrite. Fine- to medium-grained plagioclase aggregates could be pseudomorphous after garnet, or amygdules (Figure GS2020-5-4b). Pillows are densely packed, flattened and vary in size. They are up to 30 cm in the longest direction. Pillow selvages are about 5 cm thick and very dark grey-green. Top indicators for the pillowed basalt were obscured by deformation.

Quartzite with minor schistose layers (unit 1c)

Quartzite is spatially associated with massive basalt (unit 1a) on the south shoreline of the northern arm of Russell Lake (Figure GS2020-5-2; Martins and Couëslan, 2020a). This unit is light rusty grey on weathered surfaces and dark grey where fresh, fine grained, nonmagnetic and compositionally layered with minor intervals of schist (variable but typically 5–10 cm wide). This quartzite is nearly 98% quartz, with 1–2% graphite and trace to 1% sulphide. Local, strongly gossanous beds contain 80–90% quartz, 1–3% sulphides and up to 15% graphite.

Diopside gneiss and associated marble (unit 1d)

Diopside gneiss is found associated with marble, and both are spatially associated with massive basalt (unit 1a). The diopside gneiss is well layered, foliated to strongly foliated, nonmagnetic, coarse grained, and very dark grey when weathered and dark green-grey when fresh. The mineralogy of this unit is highly variable: 30–60% quartz, 15–20% diopside, 2–3% titanite, and plagioclase. The marble component is commonly recessively weathered (Figure GS2020-5-4c) and composed mainly of carbonate (60–70%), diopside (10–15%) and scapolite (10–20%). Marble appears to be conformable with

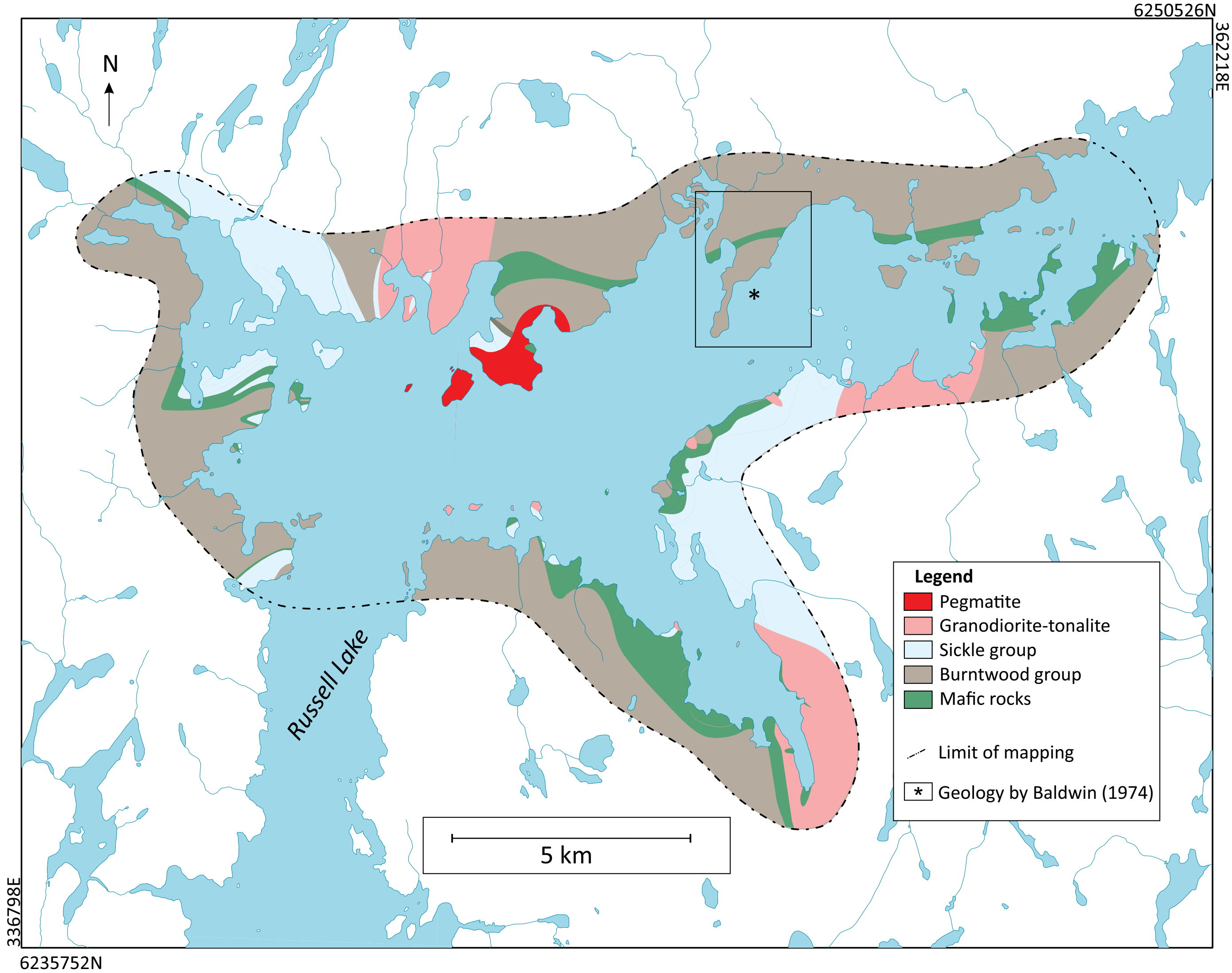


Figure GS2020-5-2: *Simplified geology of the northern arm of Russell Lake (after Martins and Couëslan, 2020a).*

the gneissosity and occurs in pods or lenses. At one locality, marble outcrops for more than 10 m across strike and is nonmagnetic, medium grained, black where weathered (due to lichen cover) and grey-green when fresh. Marble at this location consists of carbonate with diopside (10–20%), phlogopite (2–3%), serpentinized olivine (3–5%), graphite (1%) and both pyrite and chalcopyrite (trace to 1%). Diopside gneiss contains sparse chert layers 20–40 cm wide. The chert is internally layered and composed of quartz (95–98%); pyrite, chalcopyrite and pyrrhotite (trace to 1%); and trace amounts of graphite, titanite and diopside.

More diopside-rich zones (25–35% diopside) within the gneiss are characterized by rusty weathering and abundant sulphides (2–3% pyrrhotite and minor chalcopyrite). Local gossanous layers occur throughout the diopside gneiss and marble unit. Pending the results of whole-rock geochemistry, the diopside gneiss and associated marble are tentatively interpreted as carbonate-altered mafic volcanic rocks.

Burntwood group rocks

Garnet-biotite greywacke (unit 2)

Outcrops of Burntwood group garnet-biotite greywacke were described in detail by Martins and Couëslan (2019b) and will not be described again here. Outcrops in the northern arm of Russell Lake have similar characteristics, consisting of monotonous and rhythmically interbedded psammitic and pelitic layers with local pods of calcsilicate and sparse iron formation. The lack of unique marker horizons, combined with ubiquitous isoclinal folding, does not allow for the subdivision of Burntwood group rocks into smaller stratigraphic packages, nor for the tracing of stratigraphy between outcrops. However, it is noted that, toward the east end of the northern arm of Russell Lake, Burntwood group rocks are typically more pelitic.

As pointed out by Martins and Couëslan (2019b), the Russell–McCallum lakes area shows clear evidence of, and economic potential for, graphite mineralization. Assay results from

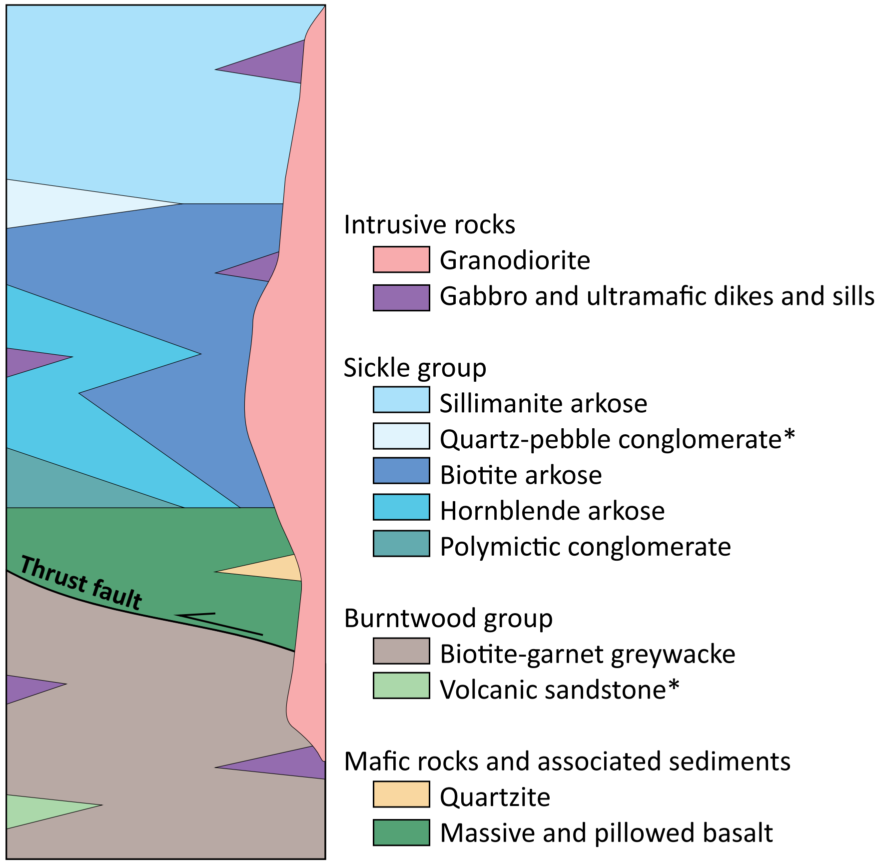


Figure GS2020-5-3: *Idealized, schematic stratigraphic column of the Burntwood and Sickle group rocks at Russell Lake; asterisks indicate rock units not observed in the northern arm of the lake (modified from Martins and Couëslan, 2019b).*

the 2019 field season revealed up to 3.31 wt. % total carbon in Burntwood group rocks (Martins and Couëslan, 2020b). The same authors also noticed that it is not possible to obtain a clear relationship between the graphite content and the composition of the Burntwood group rocks (psammitic versus pelitic bulk compositions), and that it is possible the graphite is widespread throughout the Burntwood group sequence. Graphitic horizons can also be associated with enrichments in several transition metals. A graphitic sulphide-facies iron formation (>5 m thick) on the west shore of McCallum Lake was found to contain 0.82 wt. % total carbon, 63.8 ppm Co, 609 ppm Cu, 377 ppm Ni, 73.8 ppm Mo and 22.2 ppm U (Martins and Couëslan, 2020b).

Sickle group rocks (units 3–6)

Martins and Couëslan (2019b) distinguished five different arkosic rock units within the Sickle group (listed by inferred stratigraphic order): polymictic conglomerate, hornblende arkose, biotite arkose, quartz-pebble conglomerate and sillimanite arkose. In the northern arm of Russell Lake, the quartz-pebble conglomerate is absent, whereas all other units were identified. A sillimanite-garnet arkosic unit was identified in the northern arm of Russell Lake that was not distinguished by Martins and Couëslan (2019b).

Polymictic conglomerate (unit 3)

Polymictic conglomerate is well exposed in the central area of Russell Lake's northern arm, in contrast to the rare outcrops found in the south basin of the lake. Outcrops of this unit are highly deformed (L>S), but pebbles and cobbles are discernible (Figure GS2020-5-4d). The polymictic conglomerate is magnetic and varies from matrix to clast supported, with clasts varying in size (up to 30 cm but typically <15 cm across). Composition of the clasts varies from felsic to mafic (local quartz cobbles and pebbles were observed) and the matrix is plagioclase rich, with hornblende (15–20%), quartz (10–20%), green amphibole (5–10%), biotite (5–8%) and magnetite (trace to 1%). Discrete late quartz veins cut the unit.

Hornblende arkose (unit 4)

This unit typically occurs at the contact with massive basalt (unit 1a). It is overlain by biotite arkose (unit 5) and locally underlain by polymictic conglomerate (unit 3; Martins and Couëslan, 2019a, b). Where it was observed in the northern arm of Russell Lake, the unit is layered. Compositional layering consists of 2–4 cm wide light grey layers alternating with 5–10 cm wide dark grey layers, and reflects variations in the mafic mineral content. Hornblende arkose is medium grey and weathers to dark grey, and is foliated, nonmagnetic to weakly

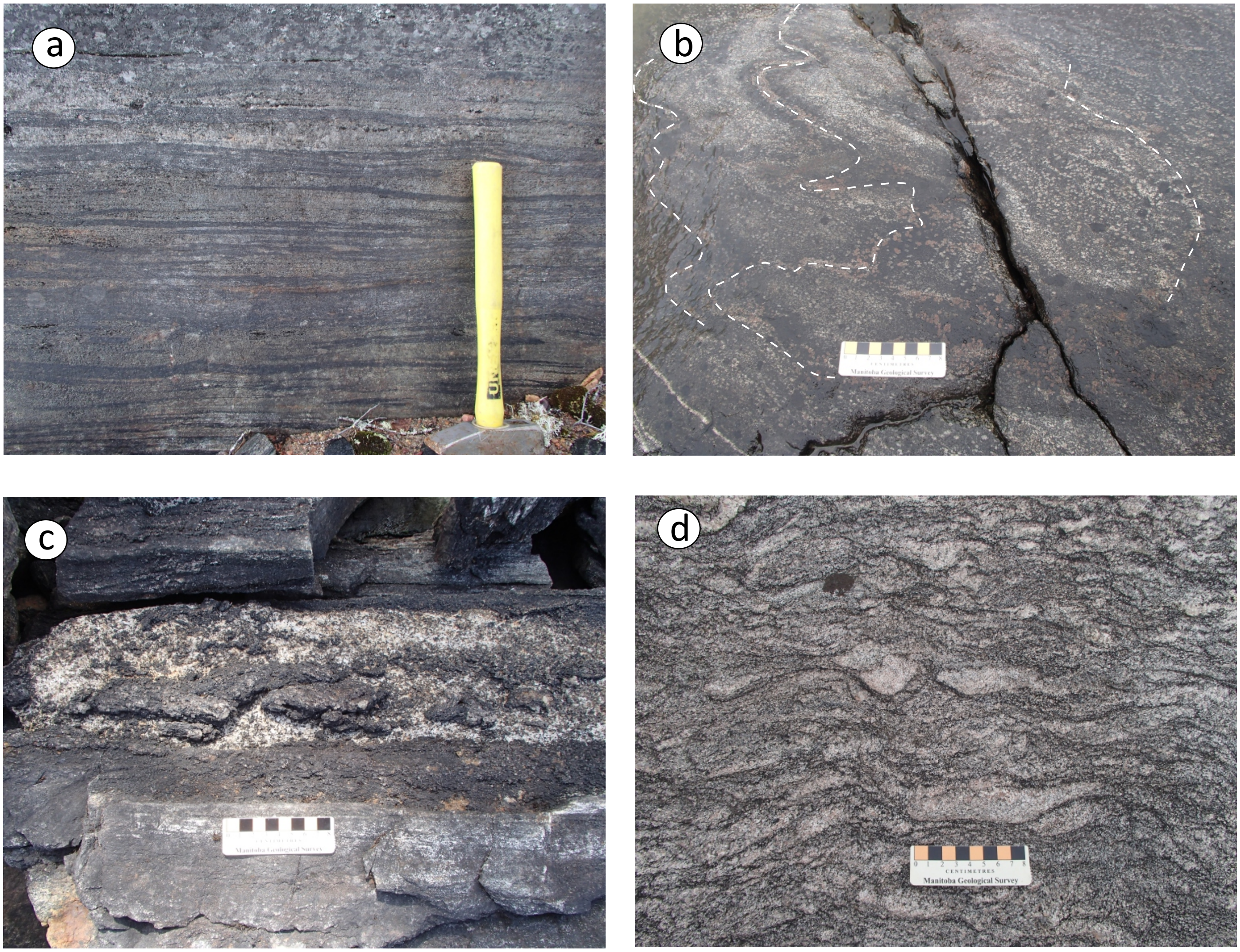


***Figure GS2020-5-4:** Outcrop photographs from the northern arm of Russell Lake: **a)** massive basalt (unit 1a, with green layers that could be the product of calcsilicate alteration; **b)** pillowed basalt (unit 1b) characterized by dark pillow selvages (dashed lines); **c)** recessively weathered marble associated with diopside gneiss (unit 1d); **d)** polymictic conglomerate (unit 3).*

magnetic and medium grained. It contains feldspar (40–50%), quartz (25–30%), hornblende (15–20%, locally up to 30%), biotite (5–7%) and magnetite (trace).

Biotite arkose (unit 5)

Biotite arkose is light pink-grey and weathers to light grey. It is medium to coarse grained, layered to locally laminated, magnetic and foliated with minor isoclinal folds. Composition of the biotite arkose is similar to that described by Martins and Couëslan (2019b), typically consisting of quartz (30–40%, locally up to 50%), feldspar (20–30%), biotite (7–10%, locally up to 20% in more aluminous layers) and magnetite (trace to locally 2%). Layering typically consists of thin biotite-enriched laminations (2–3 mm) alternating with thicker quartzofeldspathic layers (<10 cm). Local calcsilicate layers and nodules are composed mostly of epidote, quartz and plagioclase, with local carbonate. Local pods of leucosome were also identified (commonly <7 cm wide).

Sillimanite arkose (unit 6)

Sillimanite arkose is dark grey when weathered to light pinkish grey when fresh. It is medium grained, foliated, bedded and magnetic, and locally contains calcsilicate layers. Sillimanite arkose contains quartz (30–40%, locally up to 50%), plagioclase and K-feldspar (30–50%), biotite (3–5%), sillimanite (up to 20% in the more aluminous layers) and magnetite (trace to 1%). As described by Martins and Couëslan (2019b), the amount of sillimanite in this unit can be variable, with less aluminous horizons containing 3–5% and more aluminous sections containing higher modal percentages. Sillimanite commonly occurs along foliation planes; in more aluminous layers, it occurs as abundant sillimanite knots that are typically 2–10 cm in size.

Sillimanite-garnet arkose (unit 7)

A sillimanite-garnet arkosic unit was identified in several outcrops in the northern arm of Russell Lake. This unit contains sillimanite, garnet and locally cordierite. Martins and Couëslan (2019b) identified a similar unit in very few outcrops in the south basin of Russell Lake. At the time, the authors suggested this was a variety of biotite arkose.

Typically, the sillimanite-garnet arkose is magnetic, pinkish grey when weathered and medium grey when fresh, fine grained, well banded and foliated, and migmatitic with minor injections of felsic melt. Mineralogy is highly variable, namely quartz (40–50%), K-feldspar (10–30%), biotite (15–20%), plagioclase (10–15%), sillimanite (up to 7%), garnet (up to 5%), cordierite (2–3%), magnetite (trace to 1%) and trace amounts of pyrite. Locally, a porphyroblastic texture was observed in this unit, with a higher K-feldspar and biotite content than what is typically described for the sillimanite arkose unit elsewhere on Russell Lake, as well as sparse garnet (Figure GS2020-5-5a). In some occurrences, the sillimanite-garnet arkose can be difficult to differentiate from the Burntwood group greywacke, but the arkose is typically magnetic and does not contain graphite.

The stratigraphic position of the sillimanite-garnet arkose is presently unknown. It is possible that this unit represents a shoreface deposit, which would be transitional between the coeval terrestrial Sickle and marine Burntwood groups. The sillimanite-garnet arkose is similar to descriptions of interlayered pelite and quartzite considered as the shallow-water marine facies that forms the top of the Burntwood group (Zwanzig and Bailes, 2010). Alternatively, it could represent compositional variations of either the sillimanite arkose or biotite arkose, and/or the effects of varying metamorphic conditions that resulted in different metamorphic mineral assemblages (e.g., the incongruent reaction of biotite + sillimanite + quartz to produce cordierite + garnet + melt/K-feldspar). Another possible interpretation is that this sillimanite-garnet arkose is a basal unit of the Sickle group, as described by Lenton (1981), who also noted a pelitic gneiss with variable stratigraphic position.

Further investigation, including petrography and results from whole-rock geochemistry, is required. Current field observations favour the interpretation of the sillimanite-garnet arkose as a separate, mappable arkosic unit with an unknown position in the current stratigraphy.

Figure GS2020-5-5: *Outcrop photographs of rocks from the Russell Lake area:* ***a)*** *porphyroblastic texture of garnet-sillimanite arkose, Sickle group (unit 7);* ***b)*** *mafic xenoliths in granodiorite (unit 9);* ***c)*** *altered tonalite (unit 10) that appears bleached.*

Mafic dikes (unit 8)

Mafic to ultramafic dikes and sills were identified in the south basin of Russell Lake intruding rocks of both the Sickle and Burntwood groups. Although also present in the current map area, their occurrence is not as prevalent. The intrusions are typically <40 cm in width but reach up to 2 m. They are black, medium grained, foliated and locally boudinaged, and range from nonmagnetic to magnetic. The composition is similar to what was described by Martins and Couëslan (2019b), namely hornblende (70–80%), plagioclase (10–15%, locally up to 30%), biotite (1–2%) and trace amounts of magnetite. The mapped dikes are not large enough to be represented at the 1:20 000 mapping scale.

Granodiorite (unit 9)

Granodiorite is medium to dark pinkish grey and weathers light grey to beige. The rock is medium to coarse grained, foliated and slightly magnetic. It is relatively homogeneous, with local pods of leucosome and pegmatite injections. Local exposures display a discontinuous, almost subhorizontal gneissosity. This granodiorite is typically composed of 40–50% plagioclase, 20–30% quartz, 15–20% K-feldspar and 5–8% biotite, with trace amounts of apatite. Local outcrops of granodiorite contain xenoliths of massive basalt (unit 1a) that vary in size from 5 to 30 cm. The rafts are usually rotated and randomly oriented (Figure GS2020-5-5b). Local, partially digested xenoliths of Burntwood and Sickle group rocks can also be present in this granodiorite.

Tonalite (unit 10)

Tonalite is nonmagnetic to slightly magnetic, pale beige-white where weathered and light grey-blue where fresh. This unit is medium to coarse grained, foliated and cut by late brittle faults (trending mainly east). Local shear bands 10–50 cm in width exhibit sinistral sense of movement. It typically contains green-brown amphibole or pyroxene (3–5%), biotite (5–8%), titanite (trace amounts) and local graphite (1%), with the remainder being quartz and plagioclase (locally epidotized). In some outcrops, the only mafic mineral identified is biotite. Locally, a ‘pockmarked’ texture is caused by the weathering of aggregates of biotite, dark green amphibole and garnet. The pockmarks are 0.5–0.8 cm wide and make up as much as 5% of the weathered surface. An aplitic phase of the tonalite is locally present. Rare xenoliths of the local country rock were also observed.

In general, pods of carbonate alteration (~20 cm wide) are rare in tonalite; however, one outcrop was characterized by pervasive alteration. The altered tonalite appears bleached (Figure GS2020-5-5c) where weathered and is medium grey where fresh. It is medium to coarse grained, strongly gneissic and nonmagnetic. Composition is similar to the unaltered tonalite. Scapolite was identified in association with carbonate pods. The carbonate pods could be cogenetic with the carbonate alteration observed in the mafic volcanic rocks. That would suggest that the tonalite was emplaced within the volcanic package prior to widespread carbonate alteration. Alternatively, the strong gneissosity could indicate primary compositional layering and the altered rock could represent altered felsic volcanic rock. Results from whole-rock geochemistry may help refine this interpretation.

Granitic pegmatite (unit 11)

As described by Martins and Couëslan (2019b), pegmatite bodies are common in the Russell Lake area and cut all other map units; however, multiple generations of intrusions are present. The pegmatite bodies are typically plagioclase dominant, but K-feldspar–dominant pegmatite bodies are also present. Other major constituents are quartz and biotite. Common accessory minerals are magnetite, muscovite, garnet and locally cordierite and sillimanite. Pegmatite bodies typically dip steeply and occur either discordant to the main foliation and gneissosity or concordant and locally folded (most likely by F_3). Most pegmatite dikes are <2 m wide (some can be up to 30 m) and unzoned or very crudely zoned, with characteristic granitic pegmatite textures such as graphic and locally comb textures. Dikes locally display both pegmatitic and aplitic zones.

Metamorphism and structure

Martins and Couëslan (2019b) provided a detailed description of the metamorphic history and structural geology of the Russell Lake area in which they summarized and integrated findings from previous workers (e.g., McRitchie 1975a, b; Lenton, 1981).

In the northern arm of Russell Lake, observations are similar to those in the southern basin, so this information will not be repeated here. However, a higher percentage of leucosome in some outcrops of the Sickle and Burntwood rocks suggests an increase in metamorphic grade in the northern arm of Russell Lake.

The majority of structures measured in outcrops are interpreted to be the result of D_3 deformation that resulted in northeast-trending isoclinal folds and associated strong linear and planar fabrics in the direction of the F_3 fold axes. Most linear fabrics observed in the map area parallel regional F_3 fold axes. Structures resulting from the D_4 and D_5 deformations are manifested by brittle faults that trend northwest. As in the south basin, the observed brittle structures postdate all phases of folding.

Economic considerations

Natural graphite has several uses, including anode material for Li-ion batteries, brake linings, lubricants, powdered metals, refractory applications and steelmaking (U.S. Geological Survey, 2019). Currently, natural graphite is a much-sought-after commodity, mainly due to anticipated demand associated with the production of Li-ion batteries. Graphite is listed by the U.S. Department of the Interior as one of 35 critical minerals for the United States (U.S. Department of the Interior) and by the European Commission as part of its list of critical raw materials for the European Union (European Commission, 2020). Total carbon analytical results from the 2019 field season (Martins and Couëslan, 2020b) revealed up to 3.31 wt. % total carbon in greywacke of the Burntwood group. Assay results of rusty layers associated with these rocks did not reveal any significant anomalies in Cu, Zn, Au or Ag. Another occurrence of graphite in the study area is graphite horizons associated with quartzite (unit 1c; found associated with massive basalt) identified during the 2020 field season in the northern arm of Russell Lake. Assay results are pending.

The diopside gneiss and marble association (unit 1d) is tentatively interpreted as carbonate-altered mafic rocks. Pervasive carbonate alteration in mafic rocks can be associated with precious and base-metal mineralization. Assays and whole-rock geochemistry will help with these interpretations.

Acknowledgments

This report and the accompanying preliminary map benefited from in-depth discussions with H. Zwanzig. His extensive knowledge of the area greatly improved the understanding of the complex geological history of this portion of the KD. Field logistical support and services provided at the Manitoba Geological Survey Midland Sample and Core Library (Winnipeg, Manitoba) by E. Anderson, C. Epp and P. Belanger were fundamental for the success of the Russell Lake project. Drafting and GIS support was provided by L. Chackowsky and A. Santucci, and is truly appreciated. Edits by M. Nicolas and C. Böhm helped improve earlier drafts of the manuscript. RnD Technical provided technical editing services. C. Steffano took careful care of layout and final editorial duties. A word of appreciation is due to the Manitoba Hydro team for water predictions and support at the Laurie River control station.

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GS2020-6

Surficial geology mapping from Manigotagan to Berens River, southeastern Manitoba (parts of NTS 62P1, 7, 8, 10, 15, 63A2, 7)

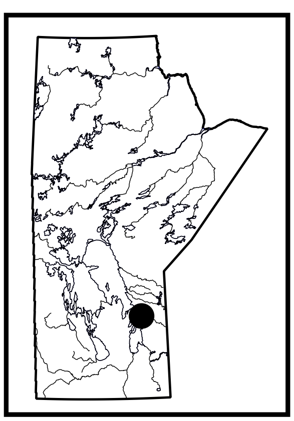
by M.S. Gauthier and T.J. Hodder

In Brief:

- Surficial mapping along the newly expanded East Side Road
- Collection of till samples to determine provenance and drift-exploration potential
- Collection of ice-flow data to reconstruct the glacial history

Citation:

Gauthier, M.S. and Hodder, T.J. 2020: Surficial geology mapping from Manigotagan to Berens River, southeastern Manitoba (parts of NTS 62P1, 7, 8, 10, 15, 63A2, 7); *in* Report of Activities 2020, Manitoba Agriculture and Resource Development, Manitoba Geological Survey, p. 41–46.



Summary

Quaternary geology fieldwork, including regional-scale surficial geology mapping, till sampling and ice-flow–indicator mapping, was conducted for 10 days in July 2020 along the newly built East Side Road between Manigotagan and Berens River in southeastern Manitoba. Sixteen 2 kg till samples were collected for matrix geochemistry (<63 µm size-fraction) and clast lithology (2–30 mm size-fraction) analysis.

Paleo–ice-flow indicators were documented at 48 field sites, and at least four ice-flow phases are recognized. Southwest-trending paleo-ice flow (220–250°) is the dominant ice-flow phase. Remnants of older ice-flow phases to the south-southeast to south-southwest and southeast were mapped, as were younger, spatially restricted, ice-flow phase(s) to the southeast.

Most of the area is covered by a veneer of glaciolacustrine silt, clay or sand (0.1 to ~1.0 m thick) over bedrock, though thicker glaciolacustrine deposits were observed (up to 2.75 m). Sparse till drapes bedrock in some of the area, at thicknesses between 0.15 and 4.0 m.

Introduction

Quaternary geology fieldwork, including till sampling and ice-flow–indicator mapping, was conducted for 10 days in July 2020 along East Side Road (constructed between 2011 and 2017) between the communities of Manigotagan and Berens River in southeastern Manitoba (Figure GS2020-6-1). A total of 93 field sites were visited to both document glacial sediments and measure the orientation of ice-flow indicators. The goals of this project were to

- conduct regional-scale mapping (sites spaced between 1 and 10 km apart);
- sample till, where present, to assess the till composition of the area; and
- map paleo–ice-flow indicators to assist reconstructions of the glacial dynamics of this area of Manitoba, which in turn guides drift exploration studies.

Physiography

The study area is located in the southeastern part of Manitoba (Figure GS2020-6-1). Elevation varies between 200 and 260 metres above sea level (m asl). Local relief is generally 1 to 30 m, generated by smooth, bare to thinly drift-covered outcrops separated by low ground.

The study area is characterized by moderately drained, mixed coniferous and deciduous forests, underlain by both mineral and organic soils. Well-drained upland sites are dominated by closed stands of medium to tall black spruce, jack pine, trembling aspen, balsam poplar and some paper birch. On sandier or rockier upland sites, more open stands of jack pine are common. Closed to open stands of black spruce, with Labrador tea and ground cover of mixed sphagnum moss and feathermoss, form the dominant vegetation on poorly drained mineral soils. On bog peatlands, the black spruce is more stunted and open.

Bedrock geology

The study area is located in southeastern Manitoba, overlying the Precambrian shield (Ermanovics, 1970) and near the margin of Paleozoic cover (Figure GS2020-6-1). The contact between the Paleozoic platform and the Precambrian shield is underwater, west of the Lake Winnipeg shoreline (Bezys, 1996; Todd et al., 1997). Road-access bedrock mapping was also completed during this study (see Rinne, 2020).

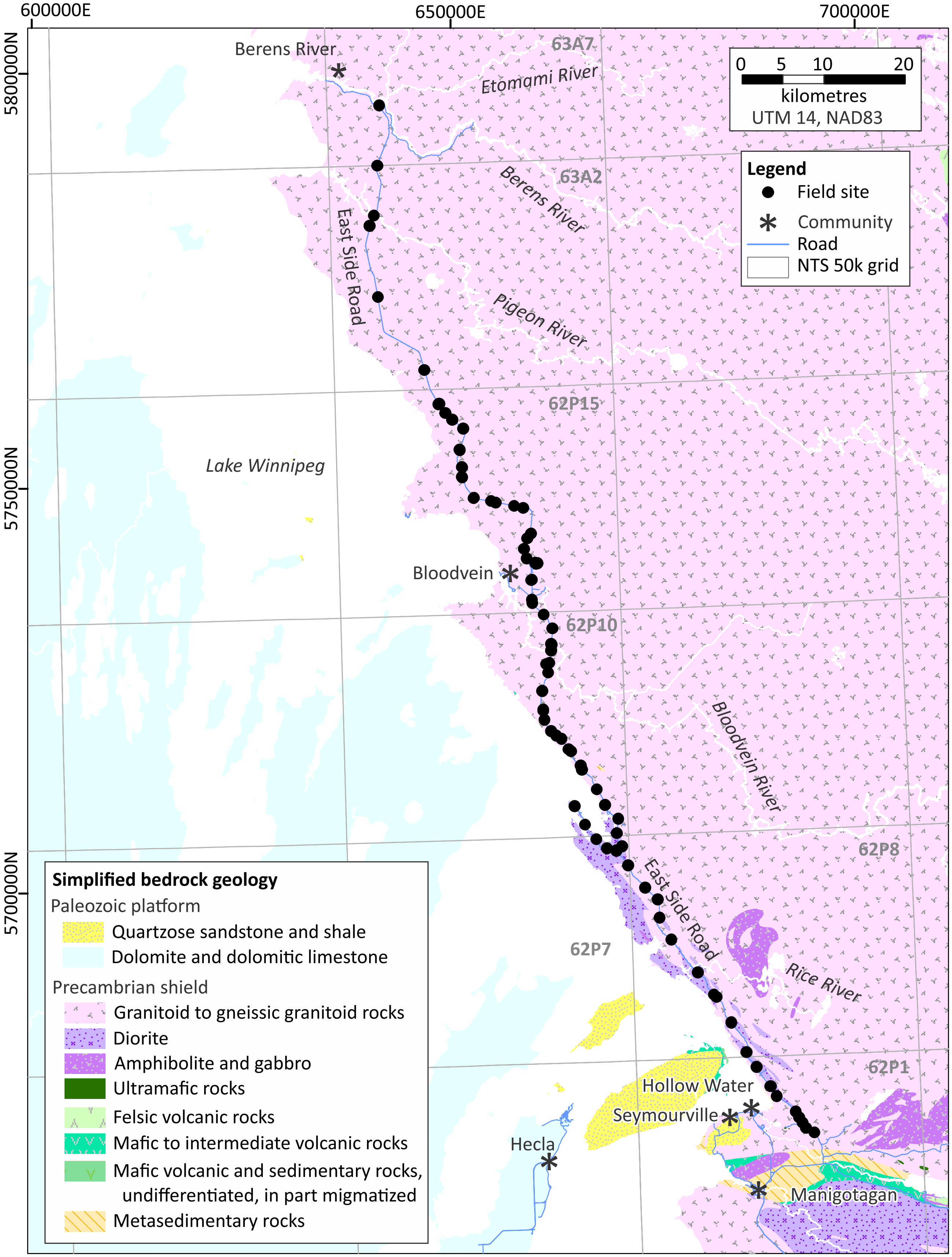


Figure GS2020-6-1: *Surficial geology field sites completed along East Side Road, southeastern Manitoba, overlain on the simplified regional bedrock geology (map modified from 1:250 000 scale unpublished Manitoba Geological Survey data). The contact between the Paleozoic platform and the Precambrian shield is underwater, west of the Lake Winnipeg shoreline.*

Surficial geology

During ice retreat, the entire study area was inundated by glacial Lake Agassiz, which resulted in extensive deposition of glaciolacustrine sediments within topographic lows. Most of the area is covered by veneers of glaciolacustrine silt, clay or sand (0.1 to ~1.0 m thick) over bedrock, though thicker deposits were observed (up to 2.75 m). Sparse till was mapped along parts of the road, amongst bedrock outcrops, at thicknesses between 0.15 and 4.0 m. Till is generally absent west of the road (and under Lake Winnipeg), as seismostratigraphic interpretations suggest fine-grained sediments deposited in glacial Lake Agassiz rest directly over bedrock within most of the lake basin (Todd et al., 1997).

Previous work

Prior to this study, the southernmost portion of the road was mapped at a 1:100 000 scale in the late 1980s (Nielsen, 1987) and at 1:50 000 scale in the 1990s (NTS 62P1, Henderson, 1998). The remainder of the area was mapped in 2004 at a reconnaissance scale using a Shuttle Radar Topography Mission digital elevation model (90 m resolution, United States Geological Survey, 2014) without ground-truthing (Matile and Keller, 2004). Till-composition surveys were conducted in the NTS 62P1 map area (Manigotagan) and adjacent NTS 52M4 map area (Henderson, 1994). Henderson collected till samples and analyzed the <2 µm (clay) and <63 µm (silt and clay) size-fractions by inductively coupled plasma–emission spectrometry (ICP-ES), atomic absorption spectrometry (AAS) following HCl digestion (<63 µm size-fraction only) and fire assay followed by inductively coupled plasma–atomic fluorescence spectrometry (ICP-AFS; Au, Pt, Pd; <63 µm size-fraction only). Texture of the <2 mm size-fraction and pebble composition of the 4 to 8 mm size-fraction was also determined.

Methods

Road-based fieldwork was undertaken over 10 days in July 2020, based out of the community of Manigotagan (Figure GS2020-6-1). A total of 93 field sites were visited to ground-truth the surficial geology mapping, collect till samples and identify ice-flow indicators. The surficial material at each field site was investigated in a road-cut exposure, a hand-dug shovel hole, a Dutch auger (1.2 m long) hole or an Oakfield soil probe hole (1.75 m long).

Sixteen 2 kg till samples were collected for matrix geochemistry (<63 µm size-fraction) and clast lithology (2–30 mm size-fraction) analysis. Till samples were collected from the C-horizon soil, except where thin till draped bedrock and only the B horizon was present. An additional six till samples (22.7 L each) were collected for heavy mineral analysis. At this time, these samples have not been submitted for analysis but will be archived for future consideration.

The orientations of striations, grooves, chattermarks and crescentic gouges and fractures were measured at 48 sites and are contained in Data Repository Item DRI2020025 (Gauthier and Hodder, 2020)[1].

Ice-flow history

New ice-flow measurements were obtained from striations, grooves, chattermarks, crescentic gouges and fractures at 48 field sites in the study area (Figure GS2020-6-2; Gauthier and Hodder, 2020). Throughout the area, construction-exposed bedrock surfaces were grooved and moulded by ice flowing to the southwest (220–255°, Figure GS2020-6-3a). Variations within this dominant flow were mapped by Henderson (1994), summarized as 227–233° followed by 250–260° and 238–245°ice flows, though some of the relative relationships at some field sites contradict this (Figure GS2020-6-2). Southwest-trending ice flow reached as far west as the community of Fisher Branch, situated 100 km west of the community of Manigotagan (Groom, 1985). There are also rarer and older preserved field-based ice-flow indicators that trend to the south-southeast to south-southwest (170–214°; Figure GS2020-6-3b). Perhaps problematically, there are also southeast-trending ice-flow indicators (108–170°) that were mapped as both older and younger than the dominant southwest-trending ice-flow phase. The older southeast-trending ice-flow indicators were mapped at four sites and include smoothed chattermarks (Figure GS2020-6-3c) and rough shovel-width grooves on protected slopes (Figure GS2020-6-3d). The younger southeast-trending ice-flow indicators were mapped at four spatially restricted sites near the community of Bloodvein (Figure GS2020-6-2), and include grooves, crescentic fractures and striations (Figure GS2020-6-3e–g). Additional southeast-trending indicators without relative age information were mapped at two sites.

Streamlined landforms were mapped, at a variety of resolutions from remotely sensed imagery (Gauthier and Keller, 2020), on the west side of Lake Winnipeg (Figure GS2020-6-2). In the Fisher Branch area, just west of the study area, late deglacial ice-flow indicators oriented toward the southeast overlie older southwest-trending striations (Groom, 1985).

The repetition and overlap between striation orientations probably indicates similar ice-flow events formed over time, either during the interaction of several ice lobes or over a longer period of glaciation (cf. Henderson, 1994).

[1] MGS Data Repository Item DRI2020025 containing the data or other information sources used to compile this report is available online to download free of charge at https://www.manitoba.ca/iem/info/library/downloads/index.html, or on request from minesinfo@gov.mb.ca, or by contacting the Resource Centre, Manitoba Agriculture and Resource Development, 360–1395 Ellice Avenue, Winnipeg, MB R3G 3P2, Canada.

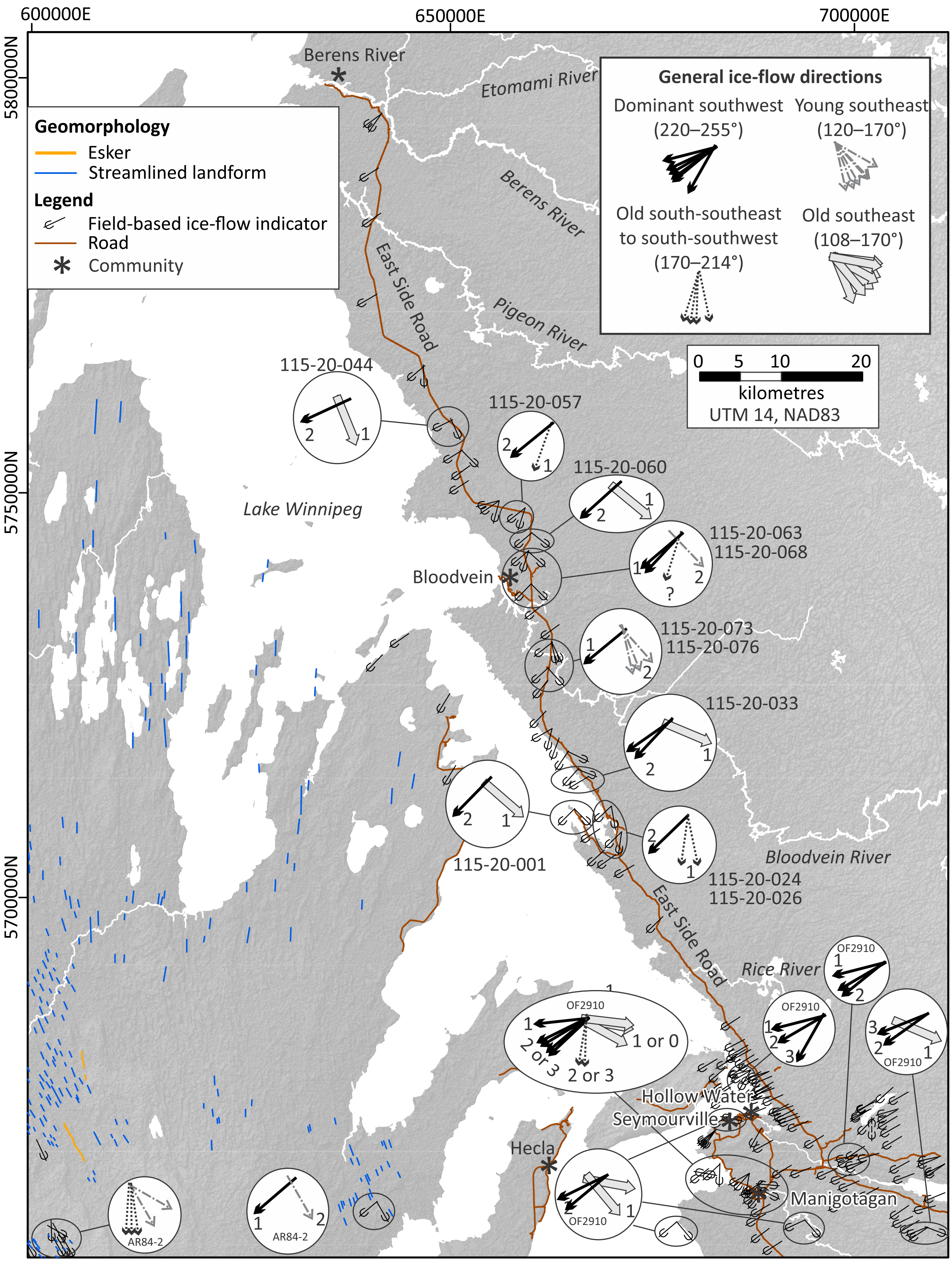


Figure GS2020-6-2: *Ice-flow–indicator data in the study area. Larger circles show a summary of the relative ages (1 = oldest) and trends of field-based ice-flow indicators for a single site or sites in close proximity to each other. The generalized ice-flow directions provide a key for differentiating between old and young ice flows of similar orientation. OF2910 refers to Henderson (1994) and AR84-2 refers to Groom (1985). Background hillshade was generated using a Shuttle Radar Topography Mission digital elevation model (United States Geological Survey, 2014).*

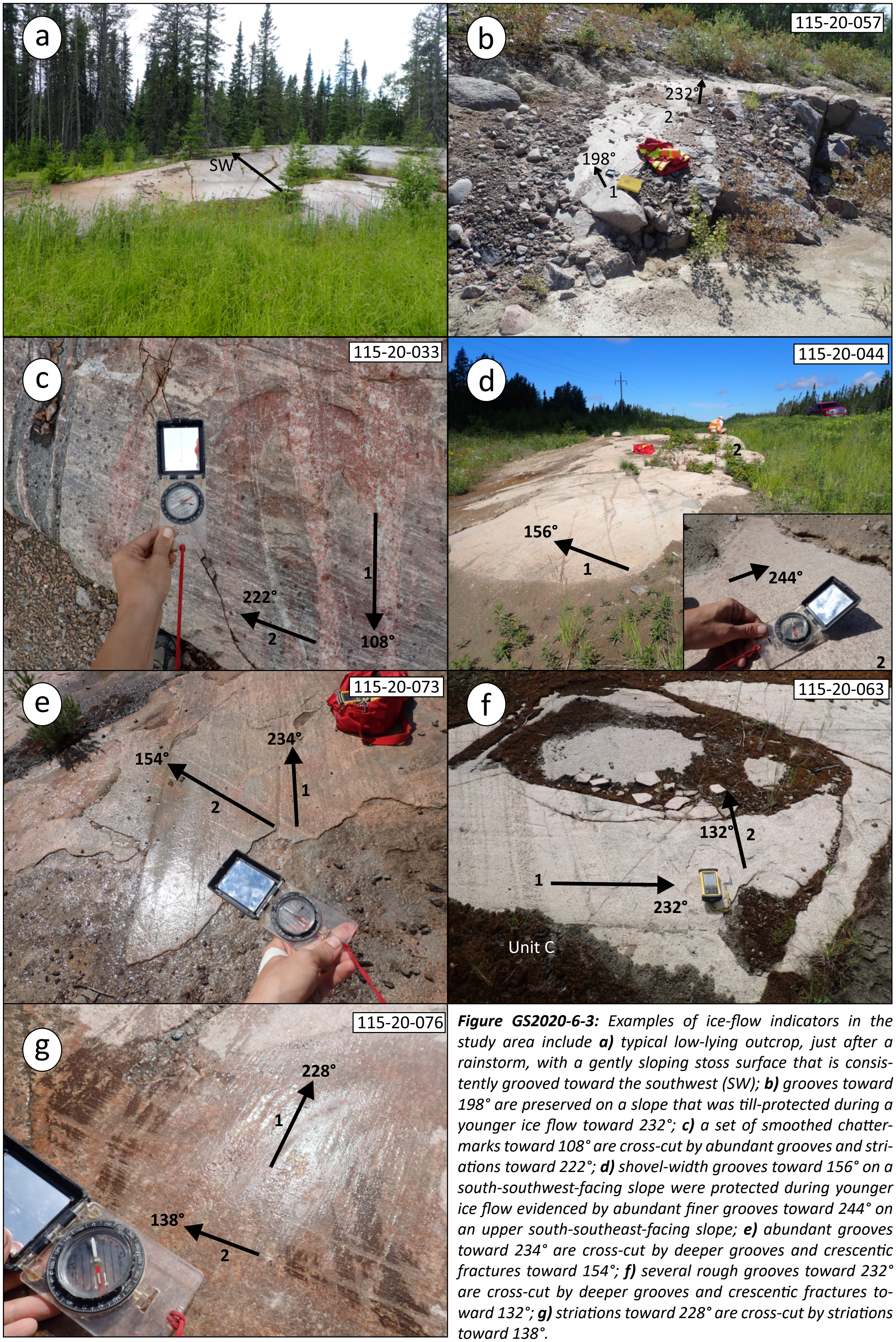


Figure GS2020-6-3: *Examples of ice-flow indicators in the study area include* ***a)*** *typical low-lying outcrop, just after a rainstorm, with a gently sloping stoss surface that is consistently grooved toward the southwest (SW);* ***b)*** *grooves toward 198° are preserved on a slope that was till-protected during a younger ice flow toward 232°;* ***c)*** *a set of smoothed chattermarks toward 108° are cross-cut by abundant grooves and striations toward 222°;* ***d)*** *shovel-width grooves toward 156° on a south-southwest-facing slope were protected during younger ice flow evidenced by abundant finer grooves toward 244° on an upper south-southeast-facing slope;* ***e)*** *abundant grooves toward 234° are cross-cut by deeper grooves and crescentic fractures toward 154°;* ***f)*** *several rough grooves toward 232° are cross-cut by deeper grooves and crescentic fractures toward 132°;* ***g)*** *striations toward 228° are cross-cut by striations toward 138°.*

Future work

Ongoing surficial geological analysis focuses on updating the 1:50 000 scale surficial mapping along the road, as well as characterizing the till composition. The latter will be accomplished by clast-lithology counts and geochemical analysis of the 16 collected till sample matrices. Results of these analyses will

- provide a better understanding of the surficial geology variability in the area;
- identify favourable geochemical or mineralogical indicators within till to aid mineral exploration; and
- establish compositional till characteristics (where sparse till is present).

Economic considerations

A thorough understanding of surficial geology is essential for drift prospecting in Manitoba's largely drift-covered regions. Till-sample analysis is commonly used in drift-covered regions to help determine the source area for mineralized erratics and boulder trains. Interpretation of till composition depends on exactly what material was sampled, as well as detailed attention to the potential for palimpsest dispersal patterns in areas that have been modified by more than one ice advance and transport direction. The extensive glaciolacustrine deposits and the sparse till deposits suggest different exploration tools are necessary in this area.

Acknowledgments

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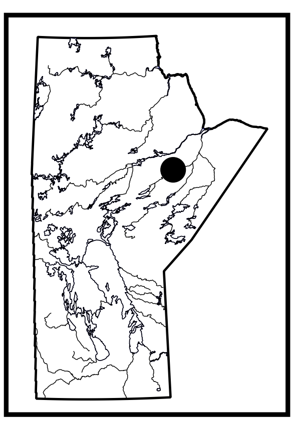
GS2020-7

Surficial geology mapping and till composition of the western Fox River greenstone belt area, northeastern Manitoba (NTS 53M15, 16)

by M.S. Gauthier and T.J. Hodder

In Brief:
- Surficial mapping in NTS 53M15 and 53M16
- Collection of till samples to determine provenance and drift-exploration potential, including for diamonds
- Collection of ice-flow data to reconstruct the glacial history and aid drift exploration

Citation:
Gauthier, M.S. and Hodder, T.J. 2020: Surficial geology mapping and till composition of the western Fox River greenstone belt area, northeastern Manitoba (NTS 53M15, 16); *in* Report of Activities 2020, Manitoba Agriculture and Resource Development, Manitoba Geological Survey, p. 47–54.



Summary

Quaternary geology fieldwork, including till sampling and ice-flow–indicator mapping, was conducted over a portion of the buried Fox River greenstone belt in northeastern Manitoba (NTS 53M15, 16). Field sites were visited to ground-truth the surficial geology mapping, collect till samples and identify ice-flow indicators. Eighty-nine 2 kg till samples were collected for geochemical (<63 µm size-fraction) and clast-lithology (2–8 mm size-fraction) analyses. An additional 59 till samples (11.4 L each) were collected for kimberlite-indicator-mineral analysis. This work was completed during year one of a two-year project.

Paleo–ice-flow indicators were documented at 14 sites, from both erosional field-based ice-flow indicators and till fabrics. The till-fabric interpretations suggest young south- to south-southwest-trending ice flow (180–200°) and either a northwest- or southeast-trending ice-flow (300–320° or 120–140°). Older ice-flow phases were oriented to the northwest, northwest-southeast (bimodal, possibly twice), west (twice) and southwest. The study area is covered by erosional streamlined landforms, which trend toward the southwest (~245°) and were formed by the deglacial Hayes Lobe of the Laurentide Ice Sheet.

Parts of the study area are covered by a veneer of glaciolacustrine clay or silt (0.1 to ~1.0 m thick), though thicker glaciolacustrine deposits were observed (up to 1.5 m). Till varies in thickness from 0.1 to 14.0 m; thicker quaternary sediment packages are possible.

Introduction

Quaternary geology fieldwork, including till sampling and ice-flow–indicator mapping, was conducted for 24 days in August 2020, over a portion of the buried Fox River greenstone belt in northeastern Manitoba (NTS 53M15, 16). A total of 318 sites were visited to both document glacial sediments and measure the orientation of ice-flow indicators. The goals of this project are to

- conduct reconnaissance 1:50 000 scale mapping (sites spaced roughly 4 km apart), with in-fill mapping to be completed in 2021;
- sample till to assess the till composition of the area;
- sample till to analyze for kimberlite-indicator minerals (KIMs); and
- conduct paleo–ice-flow mapping to assist reconstructions of the glacial dynamics of the area, which in turn guide drift exploration studies in northeastern Manitoba.

Bedrock geology

The study area is underlain by rocks of the Fox River greenstone belt, which is part of the circum-Superior belt in northeastern Manitoba (Figure GS2020-7-1). The Fox River belt demonstrates potential to host nickel±copper and platinum-group-element (PGE) mineralization (Rinne, 2018). The belt consists of sedimentary rocks (mudstone, sandstone, minor iron formation and calcareous beds), mafic to ultramafic rocks (basalt to komatiitic basalt with minor interflow mudstones) and mafic to ultramafic intrusions (serpentinized peridotite, pyroxenite, gabbro and minor leucogabbro; Rinne, 2018, 2020). Archean granitoid rocks of the Superior province border the western and southern parts of the Fox River belt, whereas the area north of the belt is dominated by Paleoproterozoic metagreywacke and derived gneiss of the Churchill province.

Quaternary history

The study area was mapped using aerial photographs at 1:250 000 scale in the late 1970s, with limited to no ground-truthing (Klassen and Netterville, 1979). The Manitoba Geological Survey (MGS) conducted 1:50 000 scale mapping to the north (Trommelen, 2013; Trommelen et al., 2014; Kelley et al., 2015; Gauthier et al., 2016) and to the south of this area (Trommelen, 2015). These

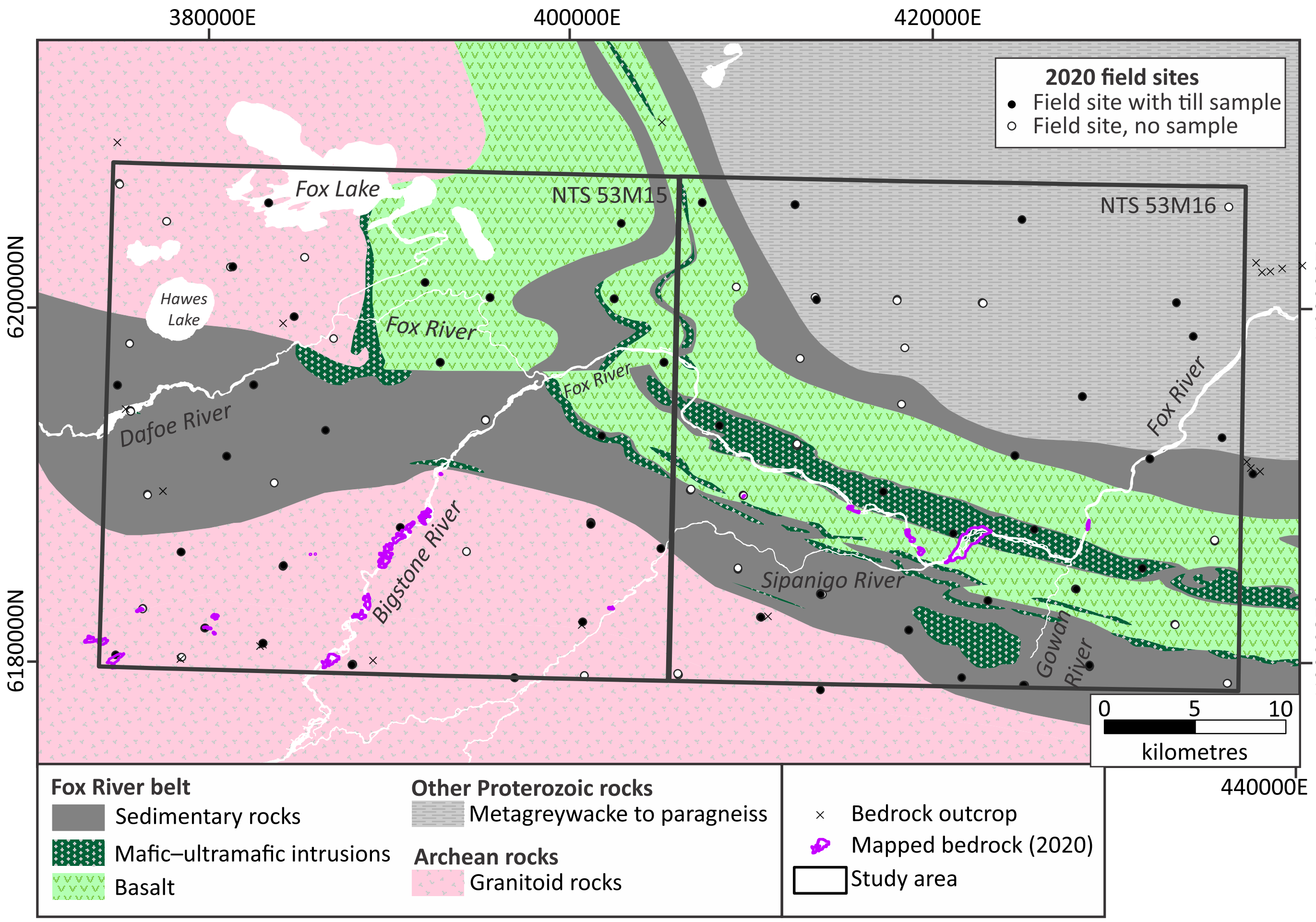


Figure GS2020-7-1: *Field sites and till sample sites overlying a portion of the Fox River greenstone belt, northeastern Manitoba. Bedrock geology is from Rinne (2018, 2020). UTM Zone 15, NAD83.*

areas are dominated by gently sloping, moderately to very poorly drained topography. Stunted spruce bogs and forests drape most areas and surface permafrost is common beneath organic deposits. Elevation varies between 68 and 198 metres above sea level (m asl). Local relief is generally 1 to 30 m, generated by smooth, bare to thinly drift-covered outcrops separated by low ground.

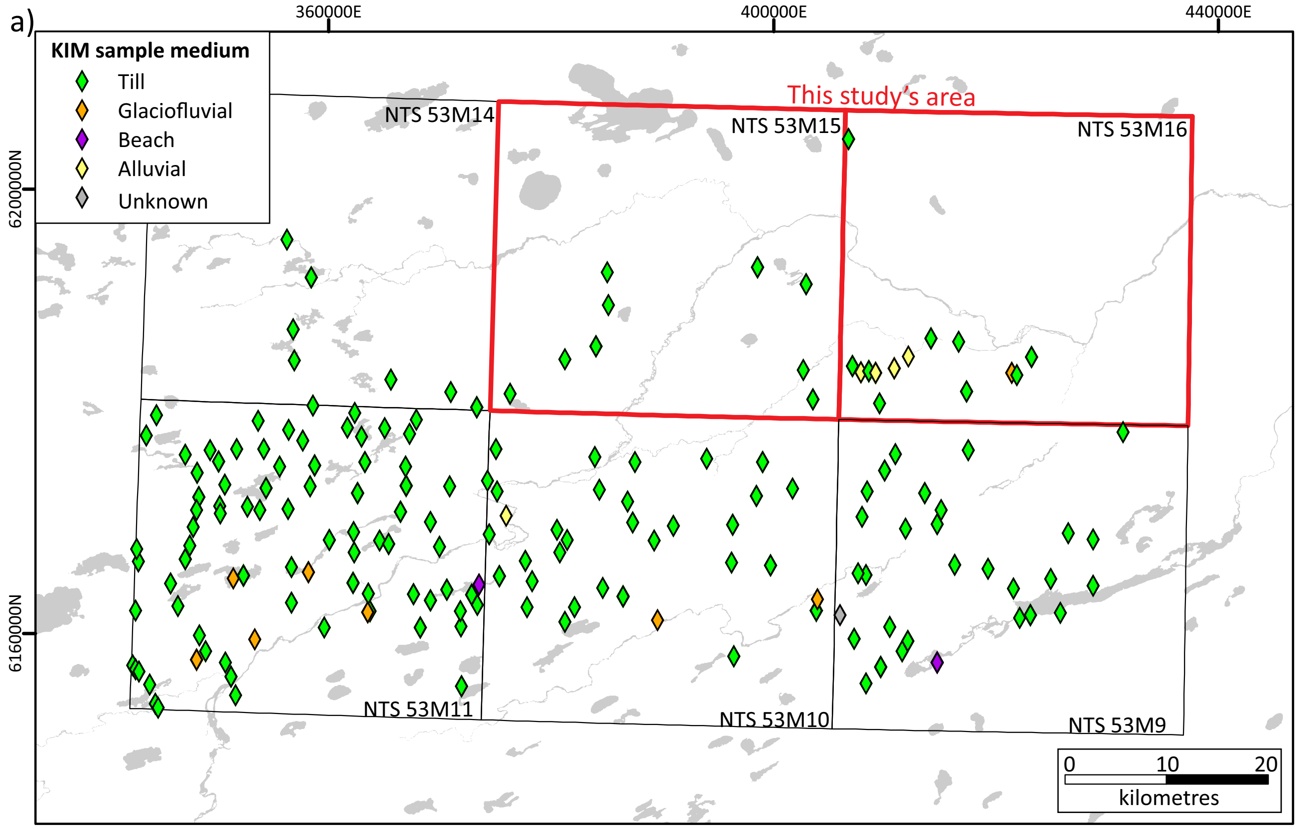
The study area was glaciated by ice flowing from multiple migratory domes of the Laurentide Ice Sheet during marine isotope stages (MISs) 2–4 (Klassen, 1986; Gauthier et al., 2019). At some point during MIS 2 a thick ice ridge, the Hudson Bay Ice Saddle, formed between two main domes (Dyke and Prest, 1987; Thorleifson et al., 1993). During deglaciation, the lobate Hayes Lobe flowed southwest from this saddle, and across the study area (Dredge and Cowan, 1989; Gauthier et al., 2019, Flowset K). The Hayes Lobe is interpreted as a late-stage erosional event, which did not affect the composition of the underlying till(s) in an area 55 km to the south (Trommelen and Ross, 2014). This two-year project will determine whether that interpretation holds true for this study area as well.

Previous diamond exploration

Regional KIM results are compiled in the MGS KIM database (Keller, 2019). The majority of the study area has not been explored, though there are some till, glaciofluvial and alluvial sediment samples that have been analyzed for KIMs (Figure GS2020-7-2a). Garnets (G10D, G9 and G3; Assessment File 948565, Manitoba Agriculture and Resource Development, Winnipeg) were reported from two alluvial samples in the southwestern corner of the NTS 53M16 map area (Figure GS2020-7-2b).

The MGS KIM database only contains results from sources that have accompanying microprobe geochemistry data (Keller, 2019). This was necessary so that a standardized classification scheme could be applied to the KIM chemistry. There are additional KIM sampling projects that only reported visual kimberlite-indicator-mineral results. Visual KIM results are not as robust as microprobe-confirmed KIMs, but they still offer insight into diamond exploration potential.

Just east of the study area, a survey conducted by BHP World Exploration Inc. in 2000 reported anomalous visual KIM



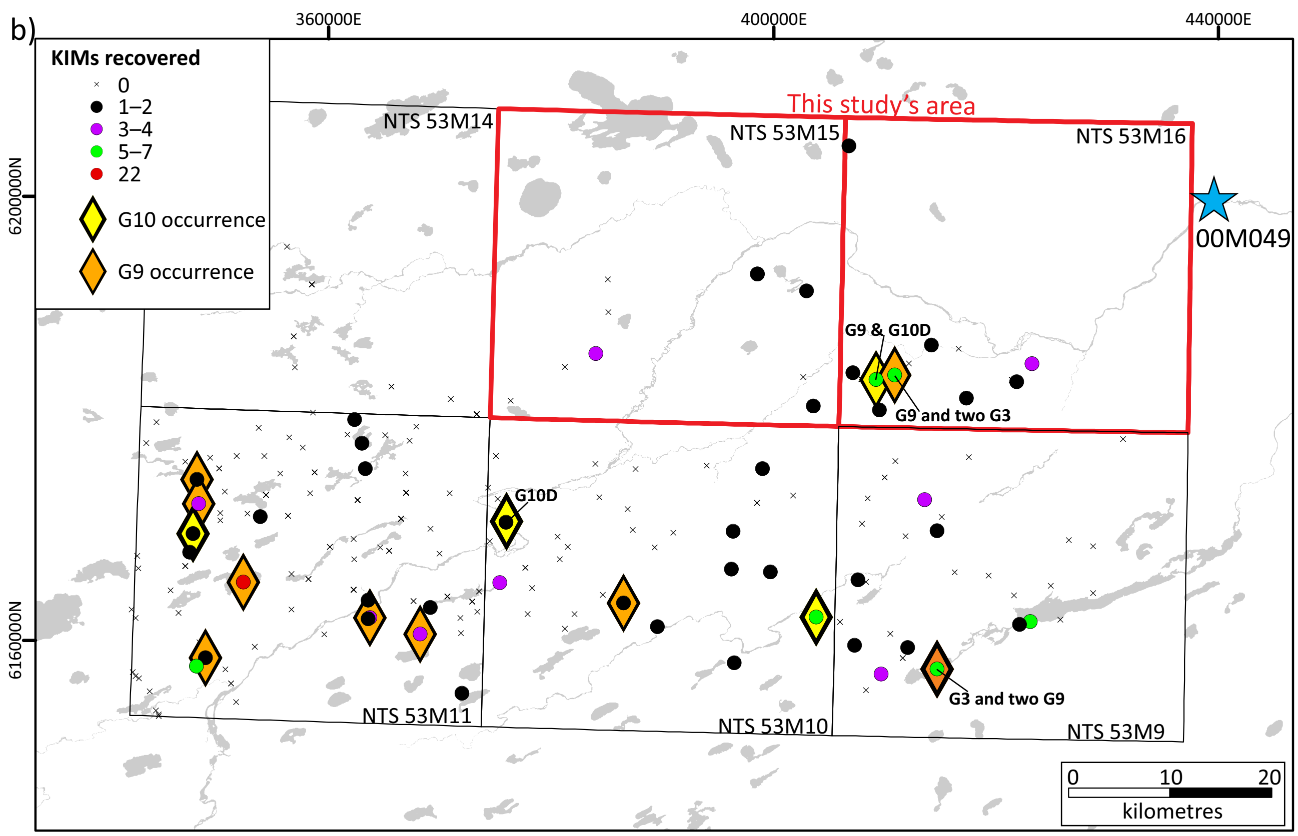


Figure GS2020-7-2: *Publicly available kimberlite-indicator-mineral (KIM) results in and around the study area including* ***a)*** *KIM samples classified according to the sample medium analyzed; and* ***b)*** *KIM recovery for each sample site. Sites that recovered G9 and G10 garnets are highlighted. Site 00M049 (blue star) recovered an anomalous quantity of visual KIMs that are not part of the Manitoba Geological Survey KIM database (Keller, 2019; see 'Previous diamond exploration' section). UTM Zone 15, NAD83.*

results (Assessment File 94830). This survey analyzed 54 samples across three separate permit areas and recovered between 0 and 23 KIMs in most samples. Interestingly, one stream-sediment sample recovered 1195 visual KIMs. The majority of grains are chromite (96%, n=1148/1195), but there were also 21 visually identified pyrope garnets (1.8%, n=21/1195). This sample was collected from a point bar on the Fox River (00M049, Figure GS2020-7-2b; Assessment File 94830). The origin of KIMs recovered from stream and river sediments are harder to trace to source, since these fluvial bodies are actively eroding both the local bedrock and sediment that has already been transported by glaciers. Regardless, this sample warrants follow-up.

Methods

Helicopter-supported fieldwork was undertaken over 24 days in August 2020, based out of the town of Gillam, which is located 40 km north of the study area. A total of 318 field sites were visited to ground-truth the surficial geology mapping, collect till samples and identify ice-flow indicators (Figure GS2020-7-1). The surficial material at each field station was investigated by means of a hand-dug shovel hole, a Dutch auger (1.2 m long) hole and/or a natural sediment exposure.

Eighty-nine 2 kg till samples were collected for geochemical analysis by partial and total digestion of the silt and clay size-fraction (<63 µm) and clast-lithology (2–8 mm size-fraction) analysis. Till samples were collected from the C-horizon soil, both at surface and at depths of up to 14 m. An additional 59 till samples (11.4 L each) were collected for KIM analysis. These samples were submitted to the De Beers Group to be analyzed through in-kind support. The KIM-sample locations are withheld, to allow equal opportunity for follow-up by all interested parties when the data is publicly released at a later date.

Results

Ice-flow history

Bedrock outcrops are rare in the study area, and new erosional ice-flow measurements were obtained from striations, grooves, chattermarks, crescentic gouges and fractures at just five field sites in the southwestern part of the study area, and one additional site along the Fox River (Figures GS2020-7-3, -4). Based on these erosional field-based ice-flow indicators, paleo ice flow was to the northwest, west, south and southwest.

Streamlined landforms were mapped across the study area, at a variety of resolutions from remotely sensed imagery (Figure GS2020-7-3). All streamlined landforms trend toward the southwest in the study area, at ~245° (Figure GS2020-7-5), and were formed by the regional Hayes Lobe (Dredge and Cowan, 1989; Gauthier et al., 2019).

Till-fabric analyses

Till-fabric analyses were conducted on the surface till at five sample sites, and on the subsurface till at an additional 11 sample sites (Figure GS2020-7-3). Preliminary interpretations suggest that the surface till was deposited and/or deformed by south- to south-southwest-trending ice flow (180–200°) and either a northwest- or southeast-trending ice-flow (300–320° or 120–140°). The till-fabric interpretations also suggest older ice-flow phases to the northwest-southeast (twice), west (twice) and southwest. Future work will reconcile these preliminary findings with the regional ice-flow history provided in Gauthier et al. (2019).

Till-fabric analyses are particularly useful in areas where bedrock outcrops are scarce. However, given that the orientations of the surface-till fabrics contradict the orientation of streamlined landforms, this study highlights the importance of conducting till-fabric analyses in all areas. The mismatch of orientations between different types of ice-flow indicators likely means that the streamlined landforms are erosional, and have exposed till(s) unrelated to the young southwest-trending ice-flow direction. Although forthcoming till-composition studies will assess this hypothesis, it should be noted that erosional streamlined-landform genesis is confirmed in the Knee Lake area, 55 km to the south (Trommelen and Ross, 2014).

Surficial geology

Preliminary comparison between the 2020 field sites and the existing reconnaissance mapping (Klassen and Netterville, 1979) shows that till at surface is more common than currently mapped (Figure GS2020-7-6). Generally though, a glaciolacustrine veneer of clay and/or silt, of variable thickness, drapes drumlinized till ridges across the study area. Wave-washed till was observed at elevations between 120 and 175 m asl, trimlines at 136 and 161 m asl and a beach at 134 m asl. Wave-washing was particularly strong in the southwestern portion of the study area, where low-lying bedrock is exposed between 170 and 185 m asl (Figure GS2020-7-1).

Future work

This report summarizes the work done during the first year of a two-year project. Ongoing surficial geology analyses will focus on 1:50 000 scale surficial mapping, as well as tracing lithological indicators from known bedrock source areas. The latter will be conducted by clast-lithology counts and analyzing the geochemical composition of the collected till samples. A second field season is planned for 2021, with similar methods to those in 2020.

Economic considerations

As bedrock outcrops are rare in much of Manitoba's northern region, a thorough understanding of surficial geology is essential for drift prospecting. Till-sample analysis is com-

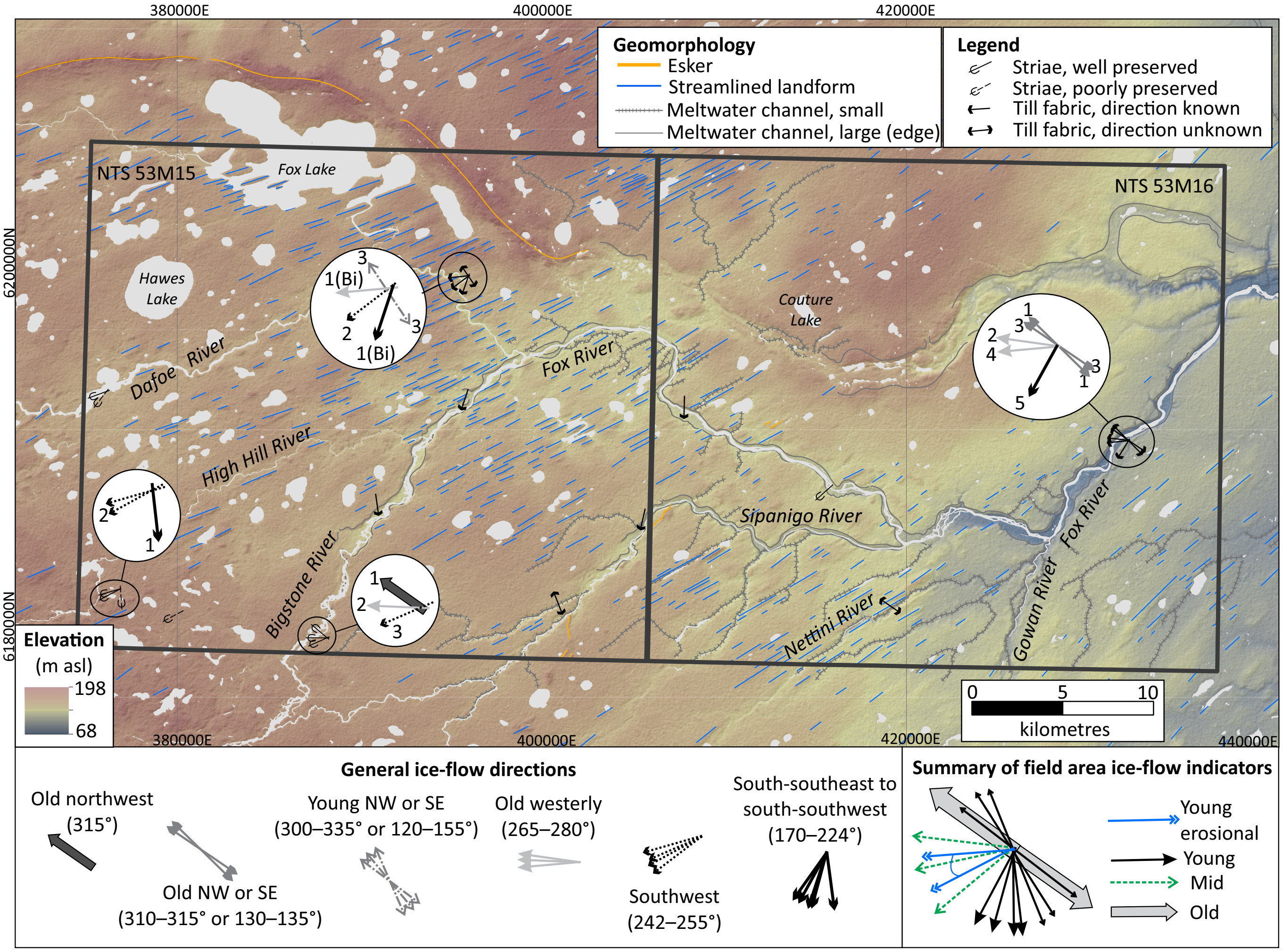


Figure GS2020-7-3: *Ice-flow–indicator data in the study area. Larger circles are a summary of the relative ages (1=oldest) and trends of ice-flow indicators for a single site or sites in close proximity to each other. The generalized ice-flow directions provide a key for differentiating between old and young ice flows of similar orientation. Background hillshade was generated using a 30 m resolution Shuttle Radar Topography Mission digital elevation model (United States Geological Survey, 2014). UTM Zone 15, NAD83.*

monly used in drift-covered regions to help determine the source area for mineralized erratics and boulder trains, but is more difficult to interpret in palimpsest terrains such as in this study area. Ongoing surficial geology studies aim to provide a detailed framework for the directions, timing and nature (e.g., erosive or depositional) of major and minor ice-flow events in the region. The outcomes of these studies are geared toward providing mineral exploration geologists with an up-to-date surficial geology knowledge base and the adequate tools to more accurately locate exploration targets in Manitoba's drift-covered areas. More specifically, the results of this study may inform drift exploration for nickel, copper and platinum-group-element mineralization in the Fox River belt, and new KIM results will help assess the regional-scale diamond potential of the study area.

Acknowledgments

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Figure GS2020-7-4: *Examples of erosional ice-flow indicators in the study area include* ***a)*** *low-lying outcrop moulded and grooved toward 250°;* ***b)*** *a 2 m wide chattermark toward 176° that was partially protected from the younger 250° ice flow;* ***c)*** *0.2 m wide chattermarks toward 270° that are adjacent to, and cross-cut by striations toward 246°; the latter were mapped at the same site as* ***d)*** *an outcrop that has been moulded and plucked toward 310°.*

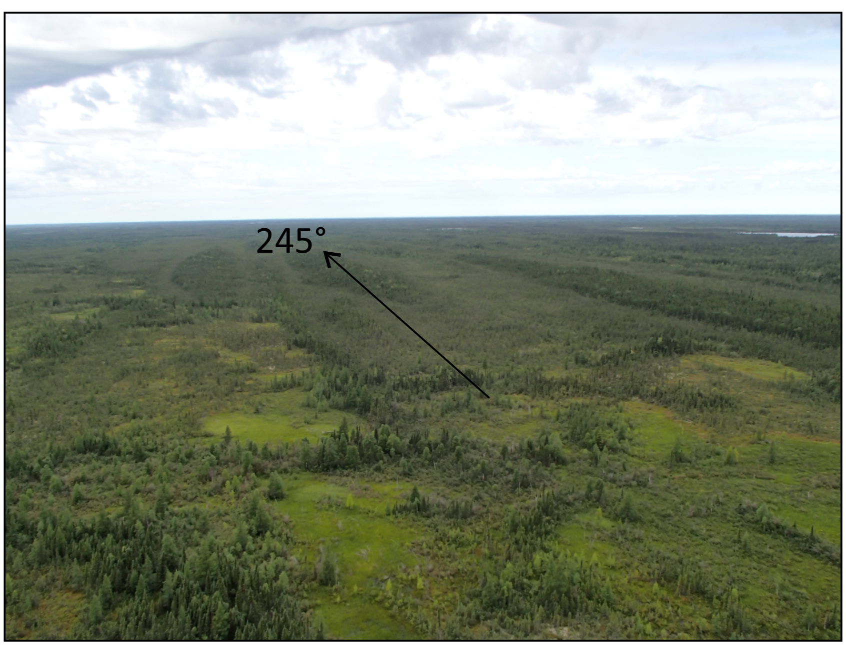

Figure GS2020-7-5: *Oblique aerial photograph of streamlined landforms in the study area.*

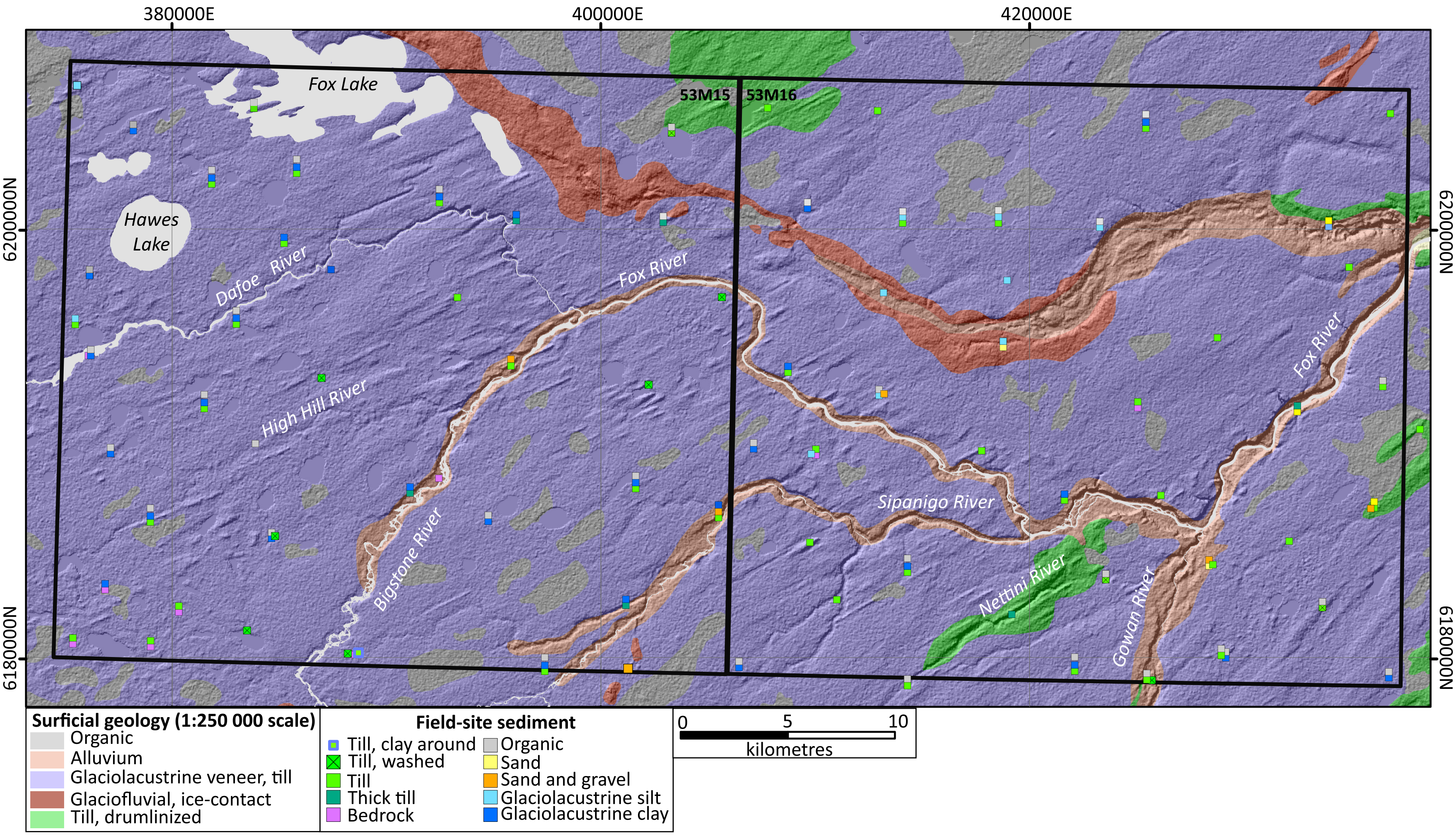

Figure GS2020-7-6: *The interpretation of sediments at the field sites are displayed overlying reconnaissance-level surficial geology mapping (Klassen and Netterville, 1979) of the study area. A hillshaded digital elevation model has been added to the background to show the regional topography (United States Geological Survey, 2014). UTM Zone 15, NAD83.*

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GS2020-8

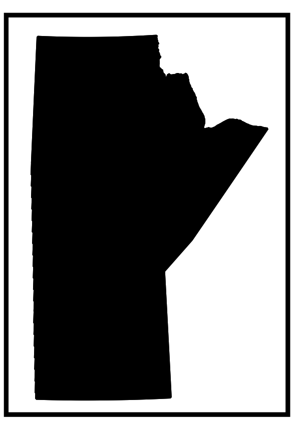
Manitoba till-matrix geochemistry compilations: update and new releases

by M.S. Gauthier

In Brief:

- Compilation of all till-geochemistry data in Manitoba
- Data available in Microsoft® Excel® for ease of use
- Statistics available to quickly quantify regional background and anomalous values

Citation:
Gauthier, M.S. 2020: Manitoba till-matrix geochemistry compilations: update and new releases; *in* Report of Activities 2020, Manitoba Agriculture and Resource Development, Manitoba Geological Survey, p. 55–58.



Summary

Four new digital datasets represent the compilation of data from all known public till-geochemistry surveys carried out in Manitoba. The datasets are separated based on analytical method and size-fraction of the till matrix. Additionally, till-matrix carbonate data from surface samples have been compiled for the entire province, and are available as a hand-contoured map. This data can be brought into GIS software and integrated with other geoscience data, to generate new exploration targets and design follow-up exploration programs.

Introduction

Four new digital datasets represent the compilation of data from all publicly available till-geochemistry surveys carried out in Manitoba (Figure GS2020-8-1). These include

- dataset 1: silt plus clay (<63 µm) size-fraction by instrumental neutron activation analysis (INAA; Gauthier, 2020a),
- dataset 2: silt plus clay (<63 µm) size-fraction by inductively coupled plasma–mass spectrometry (ICP-MS) after an aqua-regia or modified aqua-regia digestion (Gauthier, 2020b),
- dataset 3: clay (<2 µm) size-fraction by atomic absorption spectrometry (AAS) or inductively coupled plasma–emission spectrometry (ICP-ES) after aqua-regia digestion (Gauthier, 2020c), and
- dataset 4: visible gold grains in the heavy mineral (<2 mm; –10 mesh) size-fraction (Gauthier, 2020d).

The first three datasets include graphs depicting the relative abundance (background values) of important elements across Manitoba—in both calcareous and noncalcareous till. These data will enable users to quickly identify if or where an element concentration is atypical for an area.

Collection methods

Till samples were collected from road cuts, borrow pits, ditches, natural exposures, hand-dug holes, Dutch-auger holes and boreholes across Manitoba. Wherever possible, till samples were collected from the C horizon in order to minimize potential weathering effects. To learn more about the characteristics of individual till samples, the reader is encouraged to view the individual project publications.

Compilation methods

The digital databases include data from 12 464 till samples collected from 53 different projects. No effort was made to reanalyze, level or otherwise standardize the data.

Carbonate in the till matrix

A significant portion of the till in Manitoba is calcareous. This carbonate has two sources—Paleozoic bedrock within the Hudson Bay Basin in the far northeast, and within the Western Canada Sedimentary Basin in the south (Wheeler et al., 1996). The net carbonate-dispersal pattern within the till is complex (Figure GS2020-8-2), and generally decreases in concentration to the west, southwest and south of Hudson Bay. The concentrations increase drastically within tills south of Flin Flon and Snow Lake, reflecting quick entrainment of calcareous detritus from the Western Canada Sedimentary Basin. Within this larger pattern, however, the calcareous surface tills locally contain a range of carbonate concentrations that relate to overprinting (dilution and/or reworking) and inheritance (preservation) during till transportation and deposition (e.g., Trommelen et al., 2013; Trommelen and Ross, 2014; Gauthier et al., 2019).

Figure GS2020-8-1: *The spatial extent of compiled till-matrix geochemistry datasets in Manitoba:* ***a)*** *dataset 1, silt plus clay (<63 µm size-fraction) by instrumental neutron activation analysis (INAA);* ***b)*** *dataset 2, silt plus clay (<63 µm size-fraction), analysis by inductively coupled plasma–mass spectrometry (ICP-MS);* ***c)*** *dataset 3, clay (<2 µm size-fraction), analysis by atomic absorption spectrometry (AAS) and inductively coupled plasma–emission spectrometry (ICP-ES);* ***d)*** *dataset 4, visible gold grains in the heavy mineral size-fraction (<2 mm). Green dots mark locations of analyzed samples.*

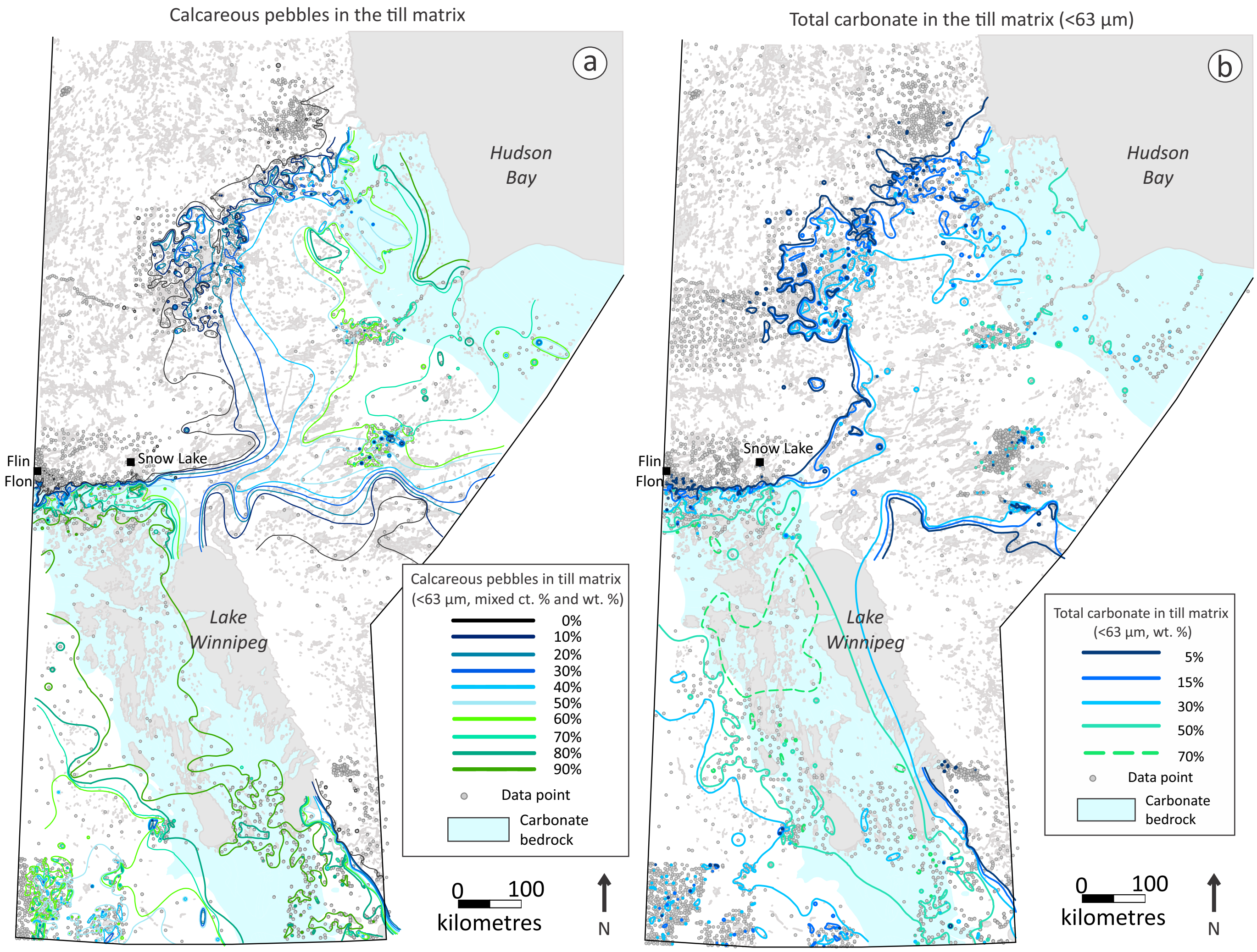


Figure GS2020-8-2: *Hand-contoured distribution of* ***a)*** *calcareous pebbles and* ***b)*** *total carbonate in the till matrix (silt plus clay, <63 µm size-fraction) of surface till samples in Manitoba. These compilations represent ongoing work and are sourced from a number of different studies with slightly different methods (Manitoba Agriculture and Resource Development, 2020). Owing to the limited number of data points in most areas, the hand-contoured data are not accurate at a detailed scale but provide a general overview of the carbonate-dispersal pattern. Similarly, the contours are more detailed where local-scale fieldwork has been conducted. The area in white is underlain by noncarbonate rocks (modified after Manitoba Department of Mines, Natural Resources and Environment, 1979).*

Prospective and background concentrations

Carbonate rocks can mask, or dilute, the 'signature' of elements important to exploration. 'Low' concentrations of desired elements in calcareous till may be more prospective than the same concentrations within noncalcareous till. The reason why a particular relationship occurs would depend on what bedrock the till is overlying, what bedrock types the till is sourced from, and what other materials may have been incorporated into the till (glaciolacustrine, glaciomarine, nonglacial sediments, etc.). In general, calcareous values should be noted and different populations may need to be treated as separate datasets.

Economic considerations

Till-sample analysis is commonly used in drift-covered regions to help determine the source area for mineralized erratics, boulder trains and anomalous lake geochemistry or geophysical data. These new till-matrix geochemistry datasets will allow users to quickly view, compile and interact with the data from various regions of Manitoba.

Acknowledgments

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DRI2019007

Whole rock geochemistry compilation of the Oxford Lake–Knee Lake greenstone belt, northwestern Superior Province, Manitoba (parts of NTS 53L6, 12–15, 53M2, 63I9, 16)

by S. Anderson and T. Martins

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DRI2019008

Compilation of Sm-Nd isotopes from the Oxford Lake–Knee Lake greenstone belt, northwestern Superior Province, Manitoba (parts of NTS 53L6, 12–15, 53M2, 63I9, 16)

by S. Anderson and T. Martins

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DRI2020001

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DRI2020002

Lithogeochemistry of drillcore from the Huzyk Creek property, central Manitoba, and the Flin Flon paleosol, west-central Manitoba (NTS 63J6, 63K13)

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DRI2020005

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DRI2020006

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by K.D. Reid

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DRI2020008

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by M. Rinne

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DRI2020011

Compilation of Sm-Nd isotope results from the Manitoba Geological Survey 2019/2020 season

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DRI2020012

Compilation of Sm-Nd isotope results from the Manitoba Geological Survey 2018/2019 season

by Manitoba Geological Survey

DRI2020013

Till geochemistry data north of Leclair Lake, northwest Manitoba (NTS 64F8)

by E. Nielsen and M.S. Gauthier

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DRI2020017

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DRI2020020

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by E. Nielsen and M.S. Gauthier

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DRI2020022

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DRI2020023

Drillcore geochemistry from the eastern sub-Phanerozoic Flin Flon domain, north-central Manitoba (NTS 63J5, 6, 11, 12, 14, 63K8, 9)

by K.D. Reid

Microsoft® Excel® file supplements:

Reid, K.D. and Gagné, S. 2016: Examination of exploration drillcore from the south Wekusko Lake area, eastern Flin Flon belt, north-central Manitoba (parts of NTS 63J5, 12, 63K8, 9); *in* Report of Activities 2016, Manitoba Growth, Enterprise and Trade, Manitoba Geological Survey, p. 74–86.

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DRI2020025

Field-based ice-flow–indicator data from Manigotagan to Berens River, southeastern Manitoba (parts of NTS 62P1, 7, 8, 10, 15, 63A2, 7)

by M.S. Gauthier and T.J. Hodder

Microsoft® Excel® file supplements:

Gauthier, M.S. and Hodder, T.J. 2020: Surficial geology mapping from Manigotagan to Berens River, southeastern Manitoba (parts of NTS 62P1, 7, 8, 10, 15, 63A2, 7); *in* Report of Activities 2020, Manitoba Agriculture and Resource Development, Manitoba Geological Survey, p. 41–46.

DRI2020026

Laser-ablation inductively coupled plasma–mass spectrometry analyses of detrital zircon grains from metasedimentary rocks in drillcores KUS378 and HAR070 in the Watts, Mitishto and Hargrave river areas, central Manitoba (parts of NTS 63J5, 6, 11–14)

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DRI2020027

Whole-rock geochemistry of the Russell Lake mapping project (2020 field season), northwestern Manitoba (parts of NTS 64C5, 6)

by T. Martins and C.G. Couëslan

Microsoft® Excel® file supplements:

Martins, T. and Couëslan, C.G. 2020: Preliminary results from bedrock mapping in the northern arm of Russell Lake, northwestern Manitoba (parts of NTS 64C5, 6); *in* Report of Activities 2020, Manitoba Agriculture and Resource Development, Manitoba Geological Survey, p. 31–40.

DRI2020028

Lithogeochemistry of drillcore from the Huzyk Creek property, central Manitoba (NTS 63J6)

by C.G. Couëslan

Geoscientific Map

MAP2020-1

Surficial geology of the Arden area, Manitoba (NTS 62J6)

by T.J. Hodder and M.S. Gauthier (scale 1:50 000)

Geoscientific Paper

GP2020-1

Geology and interpretation of graphite- and vanadium-enriched drillcore from the Huzyk Creek property, sub-Phanerozoic Kisseynew domain, central Manitoba (NTS 63J6)

by C.G. Couëslan

Open Files

OF2020-1
Digital compilation of surficial point and line features for Manitoba: datasets
by M.S. Gauthier and G.R. Keller

OF2020-2
Manitoba till-matrix geochemistry compilation 1: silt plus clay (<63 µm) size-fraction by instrumental neutron activation analysis
by M.S. Gauthier

OF2020-3
Manitoba till-matrix geochemistry compilation 2: silt plus clay (<63 µm) size-fraction by inductively coupled plasma–mass spectrometry after an aqua-regia or modified aqua-regia digestion
by M.S. Gauthier

OF2020-4
Bedrock geology of the Fox River belt, Manitoba (parts of NTS 53M–O, 54B, D)
by M.L. Rinne

OF2020-5
Manitoba till-matrix geochemistry compilation 3: clay (<2 µm) size-fraction by atomic absorption spectrometry or inductively coupled plasma–emission spectrometry after aqua-regia digestion
by M.S. Gauthier

OF2020-6
Manitoba till-matrix geochemistry compilation 4: visible gold grains in the heavy mineral (<2 mm; –10 mesh) size-fraction
by M.S. Gauthier

OF2020-7
Phanerozoic stratigraphic correlation chart for Manitoba
by M.P.B. Nicolas

Preliminary Map

PMAP2020-1
Bedrock geology of Russell Lake, northern arm, northwestern Manitoba (parts of NTS 64C5, 6)
by T. Martins and C.G. Couëslan (scale 1:20 000)

Surficial Geology Compilation Maps

Updated maps can be downloaded at https://www.manitoba.ca/iem/geo/surficial/digitalcompilation.html

EXTERNAL PUBLICATIONS

Benn, D., Linnen, R. and Martins, T. 2020: Evaluating muscovite as an indicator mineral for lithium bearing pegmatites, Wekusko Lake pegmatite field, Manitoba, Canada (abstract); GeoConvention 2020 virtual event, September 21–23, 2020, Calgary, Alberta, Program with Abstracts, URL <https://geoconvention.com/wp-content/uploads/abstracts/2020/56191-evaluating-muscovite-as-an-indicator-mineral-for-l.pdf> [October 2020].

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Dragovic, B., Guevara, V.E., Caddick, M.J. and Couëslan, C.G. 2020: Deciphering the timescales and mode of Archean orogenesis in the Pikwitonei Granulite Domain using multi-mineral petrochronology; GeoConvention 2020 virtual event, September 21–23, 2020, Calgary, Alberta, oral presentation.

Gauthier, M.S., Kelley, S.E. and Hodder, T.J. 2020: Lake Agassiz drainage bracketed Holocene Hudson Bay ice saddle collapse; Earth and Planetary Science Letters, v. 554, art. 116372, URL <https://doi.org/10.1016/j.epsl.2020.116372>.

Guevara, V.E., Dragovic, B., Caddick, M.J. and Couëslan, C.G. 2020: Slow differentiation of continental crust in an Archean granulite terrane; Geological Society of America, Annual Meeting virtual event, October 26–30, 2020, Montréal, Quebec, oral presentation.

Guevara, V.E., MacLennan, S.A., Dragovic, B., Caddick, M.J., Schoene, B., Kylander-Clark, A.R.C. and Couëslan, C.G. 2020: Polyphase zircon growth during slow cooling from ultrahigh temperature: an example from the Archean Pikwitonei granulite domain; Journal of Petrology, v. 61, art. egaa021, URL <https://doi.org/10.1093/petrology/egaa021>.

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