

Annual review by E.C. Syme

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In 2012, the Manitoba Geological Survey (MGS) embarked on a multiyear program to update geological mapping in the northern and central Superior Province, with bedrock mapping at Oxford Lake and Horseshoe Lake, and Quaternary mapping at Knee Lake. A new bedrock-mapping program was also started in the western Flin Flon Belt, in an area that had not been mapped since 1951. Lake-water levels finally allowed bedrock mapping at Sipiwesk Lake in the Pikwitonei Domain. Fieldwork continued in the Snow Lake area and the Thompson Nickel Belt (TNB), building on earlier work. New work was undertaken to better define the setting of a number of commodities, including gold (in the Rice Lake belt), rare earth elements (in southeastern Manitoba and southwest of Lynn Lake) and nickel (in the Mayville area of southeastern Manitoba).

Phanerozoic investigations focused on evaluation of the potential for shallow unconventional Cretaceous shale gas in southwestern Manitoba and the potential for petroleum in certain formations in southern Manitoba and the Hudson Bay Basin.

Collaborative programming with the Geological Survey of Canada

The Geo-mapping for Energy and Minerals (GEM) initiative, announced by the Government of Canada in 2008, is a five-year program designed to provide the geoscience information necessary to guide investment decisions leading to the discovery and development of new energy and mineral resources. The GEM-Minerals initiative in Manitoba is represented by a 2008 Geological Survey of Canada-funded airborne radiometric and magnetic survey in the Great Island area, as well as support for surficial mapping and geochronology in projects of Manitoba's Far North Geomapping Initiative. A GEM-Energy project is focused on the Phanerozoic stratigraphy of the Hudson Bay and Foxe basins.

The Targeted Geoscience Initiative (TGI) is a federally funded program that is planned and delivered jointly with the provinces and territories, which provide their own funding for their activities under the program. The TGI-4, announced in the February 2010 federal budget, is the fourth such initiative since 2000 and focuses on deep exploration. Projects to be conducted under the five-year TGI-4 are in the second year of field study.

Precambrian mapping and mineral deposit studies

Superior Province

In 2012, the Manitoba Geological Survey began a multiyear project to remap Oxford Lake, which lies in

the largest contiguous greenstone belt in the northwestern Superior Province (Anderson et al., GS-1). The Oxford Lake–Knee Lake belt is central to understanding the stratigraphy, tectonic evolution and economic potential of a large and geologically diverse region that includes some of the most prospective yet underexplored greenstone belts in the Superior craton. Results from the new mapping indicate that the supracrustal rocks in western Oxford Lake are disposed in three fault-bounded structural panels and constitute four tectonostratigraphic assemblages, each of which is characterized by a distinct association of lithofacies and was likely deposited in a unique setting. Results from the 2012 mapping program also improve understanding of the stratigraphic and structural context of known mineral occurrences and can thus be used to formulate new exploration strategies.

Reconnaissance fieldwork in the Horseshoe Lake greenstone belt (east of Lake Winnipeg) was conducted in 2012 to determine the feasibility of a more comprehensive mapping program in subsequent years (Kremer et al., GS-2). This greenstone belt has never been mapped in detail and is one of the few greenstone belts in Manitoba that has not been remapped since 1970. Access and exposure vary considerably; exceptionally low water levels in June 2012 greatly increased shoreline exposures in the Horseshoe Lake area. The belt is dominated by ca. 2735 Ma felsic–intermediate arc volcanoclastic and sedimentary rocks. Limited historical exploration work in the belt returned few encouraging gold numbers.

New geological mapping in the Cat Creek area, in the northern arm of the Bird River greenstone belt of southeastern Manitoba, focused on the Neoproterozoic Mayville intrusion (Yang et al., GS-3). The Cat Creek area contains several Archean layered mafic–ultramafic intrusions similar to those that host significant nickel–copper–platinum group element (PGE)–chromium mineralization worldwide. The mapping indicates that the Mayville intrusion can be subdivided into a lower heterolithic breccia zone and an upper anorthosite to leucogabbro zone; it consists dominantly of anorthositic gabbro, gabbroic anorthosite and anorthosite, with subordinate melagabbro and pyroxenite at the base and gabbro at the top. The M2 deposit (nickel–copper–PGE) in the Mayville intrusion has contact-style magmatic sulphide characteristics. In addition to nickel–copper–PGE sulphide mineralization, the Mayville intrusion may host chromite mineralization, as suggested by the presence of massive chromitite bands and disrupted chromitite–pyroxenite layers. Investigation of the magmatic architecture of the Mayville intrusion, together with structural and geophysical analysis, may assist in interpreting the mechanisms of emplacement and

identifying potential locations of feeder or magma conduits.

A short field program and follow-up geochemistry were conducted on the Bernic Lake and Rush Lake pegmatite groups, which are part of the Cat Lake–Winnipeg River district in the Bird River greenstone belt (Martins and Kremer, GS-4). Enrichment in rare metals, such as lithium, tantalum and cesium, suggests that these pegmatites have a potential for rare-metal enrichment in an area that is already famous for its Tanco pegmatite, a prime tantalum-lithium-cesium deposit and one of the largest pegmatites in the world. A systematic re-examination of the pegmatite groups in the Cat Lake–Winnipeg River pegmatite field is an important step in determining the temporal and genetic relationships between the various pegmatite groups, their fractionation histories and their associated rare-metal endowments.

A University of Waterloo Ph.D. study was initiated on the Ogama-Rockland gold deposit in southeastern Manitoba (Zhou et al., GS-5). Although most gold deposits in the Rice Lake belt are hosted by layered gabbro sills, basalt flows or volcanoclastic rocks, the Ogama-Rockland gold deposit is hosted by quartz (-carbonate) veins associated with brittle-ductile shear zones in granitoid rocks at the southeastern margin of the Ross River pluton. Ongoing detailed structural analysis of these veins will provide important new information to constrain exploration models, and will help draw attention to intrusion-hosted, shear-related, vein-type gold mineralization in the Rice Lake belt.

Thompson Nickel Belt–Superior Boundary Zone–Pikwitonei Domain

Recent mapping in the Paint Lake, Phillips Lake and Manasan Falls areas has resulted in the recognition of at least one new metasedimentary succession in the Thompson Nickel Belt (TNB; Couëslan, GS-6). In 2012, work in the Paint Lake area identified a supracrustal sequence occurring along the eastern boundary of the TNB, from Phillips Lake in the south to north of Paint Lake. Preliminary U-Pb ages from what are interpreted to be detrital zircons range from ca. 2850 to 2018 Ma, suggesting that the Paint sequence was deposited in the Paleoproterozoic rather than the Neoproterozoic. Similarities between the Ospwagan Group and rocks of the Paint sequence include the presence of siliceous horizons and meta-iron formation, along with local horizons of metapelite and calcareous rocks. These similarities could allow for the misidentification of Paint sequence rocks for the more economically prospective Ospwagan Group rocks. Alternatively, the Paint sequence could represent a new exploration target in the TNB.

A project was initiated to remap portions of the Archean Pikwitonei Granulite Domain in central Manitoba, with emphasis on interpretation of pre-granulite

protoliths (Couëslan et al., GS-7). In 2012, mapping at central Sipiwek Lake revealed relatively uniform, high-grade Neoproterozoic metamorphism accompanied by intense deformation. The presence of high-grade rocks with supracrustal protoliths on central Sipiwek Lake suggests that the distribution of Archean greenstone belt-type rocks in the Pikwitonei may be more widespread than previously recognized. Although mineral exploration in high-grade metamorphic terranes is challenging, a number of world-class mineral deposits are hosted in granulite-facies rocks. Studies have also suggested that high-grade metamorphism may be responsible for the localized concentration of metals in these deposits.

Flin Flon–Snow Lake–Lynn Lake

New geological mapping in the Flin Flon Belt includes work begun at Brunne Lake, northeast of Cranberry Portage (Gagne, GS-8). The Brunne Lake area is host to a former gold producer, the Gurney mine, and several gold showings. The basaltic rocks in the Brunne Lake area are part of the Flin Flon Belt's ocean-floor assemblage and have geochemical characteristics of both mid-ocean-ridge and back-arc-basin environments. By delineating major shear zones, including the Gurney Mine Shear Zone, and identifying subsidiary shear zones and associated gossans, this study aims to provide new targets for gold exploration. The presence of historical gold showings along the structure suggests that the entire length of the shear zone should be a target for gold exploration.

A continuing program of lithostratigraphic mapping was undertaken within the McLeod Road–Birch Lake thrust panel in the Snow Lake area as part of a Ph.D. study at Laurentian University (Rubingh et al., GS-9). The New Britannia mine is a structurally controlled gold deposit hosted in mafic and felsic volcanic and volcanoclastic rocks, spatially associated with the hangingwall of the McLeod Road Thrust. Improved understanding of the volcanic stratigraphy and structural history of the thrust panel hosting the mineralization has identified early structural repetition within the panel and new thrust faults, and has constrained the timing of mineralization. Further understanding of the internal geometry of the thrust panel and identification of major structural breaks will help in developing new guidelines for gold exploration at a property scale.

A reconnaissance geological investigation of the Brezden Lake intrusive complex was conducted to evaluate the potential for rare earth element (REE) mineralization (Martins et al., GS-10). This heterogeneous intrusive complex, located southwest of Lynn Lake, is hosted by Burntwood Group metasedimentary rocks and peraluminous granitoid rocks of the Kiseynew Domain. Although no carbonatite was found associated with the Brezden Lake intrusive complex, many aspects, including mineralogy, textures and geochemistry, are similar to the syenite

that hosts the carbonatite at Eden Lake. Some of the heterogeneity and mineralogy of the Brezden Lake syenite could be due to pervasive alkali and carbonate metasomatism. Geochemical results, particularly the high total of REEs, together with compositional, textural and alteration characteristics similar to Eden Lake syenite, warrant further investigation of the Brezden Lake syenite as a potentially interesting target for REE exploration.

Phanerozoic investigations

Shallow unconventional shale gas

The Shallow Unconventional Shale Gas Project started in 2008 and is a multiyear investigation of the shale-gas potential of the Late Cretaceous shale strata of southwestern Manitoba (Nicolas and Bamburak, GS-12). Project elements have included geochemistry, mineralogy, water and gas content, and stratigraphy. Most of the project thus far has been focused on outcrop data, but recent work is focusing on subsurface extrapolations and interpretations. The data collected during the project provide a geoscientific knowledge base for further study and hydrocarbon exploration in the province.

Cretaceous shale units in Manitoba, including the Ashville, Favel and Carlile formations in the southwestern corner of the province, are excellent candidates for exploration for shallow shale gas. The goal of a new Ph.D. study at the University of Calgary (Hosseininejad et al., GS-14) is to provide subsurface information from core and well-log data to aid in evaluation and exploration of this potential gas resource in southwestern Manitoba. Additionally, this study allows comparison between formations in Manitoba and their stratigraphically equivalent, producing strata in other parts of the Western Canada Sedimentary Basin. More work on sequence stratigraphy at local and basin scales will be undertaken to investigate the changes in facies and environment of deposition of the formations.

Stratigraphy

The GEM-sponsored, federal-provincial-territorial Hudson Bay and Foxe Basins Project is in its fourth and final year (Nicolas and Lavoie, GS-11). The aim of this project is to understand the sedimentological framework in the Hudson Bay Basin, to help promote hydrocarbon exploration in this underexplored region. The project has demonstrated that the Hudson Bay Basin has all the required elements for successful hydrocarbon exploration, including confirmed basinal distribution of source rocks, adequate maturation rank of the Silurian and Ordovician succession, hydrothermal dolomite and Silurian reefs to provide the reservoirs, and faults and stratigraphic relationships to provide the potential traps.

The Cretaceous Gammon Ferruginous Member, with a maximum thickness of 56 m, is present in thousands

of oil wells in southwestern Manitoba (Bamburak et al., GS-13). Relatively anomalous concentrations of REE and other metals, such as platinum, palladium, copper, nickel, vanadium and zinc, have been noted within the Gammon Ferruginous compared with other Cretaceous shale horizons. Additional geological and paleontological field investigations, combined with inorganic chemical and heavy mineral analyses of outcrop and drillcore samples from the Gammon Ferruginous Member, and other Cretaceous formations, may lead to the discovery of a new type of mineable sedimentary deposit in Manitoba.

A B.Sc. Honours study at the University of Manitoba (Eggie et al., GS-15) was conducted on the Upper Devonian (Frasnian) Duperow Formation. Very little exploration has been conducted in this formation in Manitoba and, until this study, little was known of its geology and hydrocarbon potential. The Duperow Formation and its stratigraphic equivalents are prolific oil-producing units in western Canada and the north-central United States. By understanding the geology of this formation on the eastern extent of the Western Canada Sedimentary Basin, Manitoba will be able to provide exploration companies with the basic geoscience information needed to explore Manitoba's deeper formations.

Researchers from Saturn Minerals Inc. and Indiana University (Mastalerz and Mastalerz, GS-16) report on an interval of organic-rich mudstone and dolomitic limestone (Rat Creek mudstone unit) in a coal testhole approximately 60 km southwest of The Pas. Discovery of the Rat Creek mudstone provides new evidence for the occurrence of a potential petroleum source rock in the Devonian carbonate succession of west-central Manitoba. With respect to the amount and type of organic matter, the Rat Creek unit may be regarded as a potential source rock with excellent oil-generation potential where it occurs at greater depths. The abundance of organic matter and the low maturity in the samples studied suggest that the Rat Creek unit may also locally be an excellent source of biogenic gas.

Quaternary

Quaternary geological observations, sampling of glacial till and measurements of ice-flow indicators were recorded within a 3720 km² area surrounding Knee Lake (Trommelen, GS-17). These observations will be compiled with information collected during MGS's Operation Superior (1999-2001) in the same area to produce a series of 1:50 000 scale surficial geology maps. Results from this and ongoing studies will provide new constraints to drift exploration, applicable to exploration for a variety of commodity types, including diamonds, gold, base metals, and pegmatite- and carbonatite-hosted rare element deposits.

A province-wide digital compilation of historical and new ice-flow and geomorphological data (Trommelen,

GS-18) aims to assist drift prospecting in Manitoba. Surficial geological mapping and its associated point and line feature data are also required for effective land-use planning, as well as groundwater, hydrocarbon and industrial-mineral development. In glaciated terrain, the exploration industry benefits from a greater understanding of ice-flow history. In the north, this new compilation and ongoing interpretation efforts may reveal important new information relating to the elusive diamond potential of Manitoba.

Three-dimensional mapping

The MGS is continuing to progress toward a complete three-dimensional (3-D) geological model of the Phanerozoic succession in southern Manitoba. A series of 2-D cross-sections are one key output from this work. These cross-sections are based on data compiled over a decade, with inputs including Manitoba's water-well, oil-well and stratigraphic-drillhole databases, large lake bathymetry, Lake Winnipeg seismic survey and surface datasets such as the provincial surficial geology compilation map series. A total of 134 cross-sections, each representing a 5 km wide east-west transect across the province between 49°N and 55°N latitudes, have been completed and digitized. The cross-sections will be released digitally as 'vertical maps', as well as on the new Map Gallery, and have been imported into the survey's 3-D software to form the basis of Manitoba's 3-D geological model. Manitoba's 3-D geological model and cross-sections unite disparate datasets and put them into a single standardized nomenclature. This work significantly contributes to a variety of geoscience knowledge bases relevant to Phanerozoic stratigraphy, hydrocarbon, groundwater and industrial-mineral resource development, and geological education.

Community liaison

The MGS community liaison program (Murphy, GS-19) is designed to meet the MGS mandate to provide meaningful mineral information to First Nation communities. This summer a new initiative called What on Earth, in partnership with First Nation communities, brought together youth and land-use managers to consider the postsecondary education requirements needed to achieve Earth science-related and mineral-resource sector career opportunities. Community liaison through the MGS encourages a respectful, balanced communicative approach that bridges the perspectives of Manitoba First Nation communities and the mineral-resource sector.

Compilation and partnerships

The MGS is engaged in many partnered initiatives, including contributions from the federal government, the mineral industry and several Canadian universities. These partnerships provide the MGS access to expertise and technologies that enhance our ability to provide a

state-of-the-art geoscience database for Manitoba. These programs facilitate the training of future geoscience professionals, which in 2011–2012 included three Ph.D. candidates and one B.Sc. Honours thesis project.

Mineral deposits database

The digital mineral deposits and occurrence database for Manitoba has been available on the MGS GIS Map Gallery website since November 2008 and now contains information on 2680 mineral deposits and occurrences. Included in the database is all of the information contained in the reports of the Mineral Deposit Series. Work will continue on entry of new data to incorporate recently released work contained in nonconfidential assessment files, as well as public information available on the SEDAR website. The updates from the past year will be added to the GIS Map Gallery in a November 2012 release. Addition of new occurrences and updating of existing occurrences with files that become nonconfidential are continuing processes.

Geoscience Information Services

Geoscience Information Services devoted much of the last year to supporting the conversion of the Map Gallery application on the departmental website to a new, more robust and versatile mapping tool using the latest Internet mapping technology. One of the key features of the new presentation is the inclusion of the main feature layers of the Mines Branch Map Gallery presentation in the 'Geology of Manitoba' map. This combination of geoscience data and mineral and land tenure information allows the user access to more research information in a single map presentation than in the previous Map Gallery. The new Map Gallery software adds several new or improved functions, including more robust querying of attributes, map annotation, inclusion of orthophotography where available and more versatile data-extraction tools.

Geoscience Information Services continues support for compilation programs, including sub-Phanerozoic Precambrian geology, geology at 1:250 000 and 1:1 000 000 scales, and geophysical data. Geochemical, geochronological and mineral-deposit databases are maintained by this section of the MGS. Geographic-information-system support is a critical component of these projects because of the large volumes of descriptive and analytical data available for the compilations.

The geophysical-dataset compilation project involves a collection of the nonconfidential geophysical datasets that were filed for assessment purposes. This ongoing project focuses on expanding the number of datasets and converting the data presentations to standard format, with particular emphasis on converting data to a standard map projection and datum. The compilation now includes 224 geophysical datasets that can be viewed in the Map

Gallery 'Geology of Manitoba' project and are available for free download.

Client Services and Outreach

Publications

Since the last *Report of Activities* was published in November 2011, the MGS has released reports, maps and data covering

- whole-rock geochemistry of the Burntwood Lake alkali-feldspar syenite in west-central Manitoba (DRI2012001);
- till-composition and ice-flow indicator data from the Great Island–Caribou Lake area in northeastern Manitoba (OF2011-4, also released as Geological Survey of Canada, Open File 6967); and
- four 1:50 000 scale surficial maps of the Gordon River, Stubner Lake, Great Island–Seal River and Sosnowski Lake areas (Geoscientific Maps MAP2011-1 to -4, also released as Geological Survey of Canada, Canadian Geoscience Maps 40 to 43)

The MGS continues to release the majority of its publications in print and/or CD or DVD for purchase through Publication Sales, as well as for free download from the Mineral Resources Division website.

Outreach

The MGS 'Manitoba Rocks!' program is delivered twice annually as part of its mineral-education outreach initiatives. The program offered free activities (e.g., Rock Doc presentations, gold panning, mineral and fossil collecting) for the public and through school tours during Provincial Mining Week at The Forks location in May,

and at the Children's Hospital and the annual Manitoba Mining and Minerals Convention in November. A new indoor venue was introduced at The Forks, providing more opportunity for industry to participate with activities and displays; included in 2012 were Vale, HudBay Minerals, Women in Mining (Manitoba Chapter) and the Prospectors and Developers Association of Canada's *Mining Matters* program. In addition, MGS geologists and Client Services staff contributed to Outreach programming by delivering community-based and school presentations on Manitoba's geology, mineral resources and mining industry.

Outreach aimed at increasing Aboriginal participation in exploration and mining in the province was delivered through the annual Aboriginal Mining Workshop, held in conjunction with the 2011 Manitoba Mining and Minerals Convention. In 2012, the Aboriginal theme will be integrated throughout the three-day convention program with sessions that will broaden opportunities for proactive engagement between the exploration and mining industry and Aboriginal community leaders.

Acknowledgments

Tim Corkery retired from his position as Manager of the Compilations and Partnerships Section, and Acting Chief Geologist of the Mineral Deposits Section, in December 2011. Tim's long experience with the MGS will be missed.

The careful work of MGS geologists, lab technicians, expeditors, students, cartographers, publication staff and administration went into the production of the Report of Activities 2012. Bob Davie and his team from RnD Technical carefully performed technical editing and Craig Steffano completed the final layout for publication.