

Annual review by E.C. Syme

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In 2010, the Manitoba Geological Survey (MGS) continued a major field effort in Manitoba's far north, supported in part by the Geological Survey of Canada (GSC) Geo-mapping for Energy and Minerals (GEM) program. Manitoba's Far North Geomapping Initiative included work in the Seal River region of northeastern Manitoba and the Misty Lake area of northwestern Manitoba, and Phanerozoic studies in the Hudson Bay Basin. Fieldwork continued in the Snow Lake area and the Thompson Nickel Belt (TNB), building on work started in 2008 and continued in 2009. New reconnaissance work was started on the east side of Lake Winnipeg, in the Family–Fishing lakes area.

Phanerozoic investigations focused on evaluation of the potential for shallow unconventional Cretaceous shale gas in southwestern Manitoba, three-dimensional geological modelling in southern Manitoba and collaborative work with the GSC in the Hudson Bay Basin.

This year saw the retirement of three long-term geological staff, each of whom made significant contributions to geoscience in Manitoba: Herman Zwanzig, Heather Groom and David Prouse.

Collaborative programming with the Geological Survey of Canada

The Targeted Geoscience Initiative (TGI) is a federally funded program that is co-planned and jointly delivered with provinces and territories, which provide their own funding for their activities under TGI. Targeted Geoscience Initiative 3 (TGI-3) started April 1, 2005 and ended March 31, 2010, and provided a vehicle to partner with the GSC on priority projects aimed at improving the economic sustainability of mining towns in north-central Manitoba. Products related to TGI-3 have been published, or are in preparation and will be released in the coming months. Targeted Geoscience Initiative 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 TGI-4 are in the planning stage.

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 GSC-funded airborne radiometric and magnetic survey in the Great Island area; these data were used to support the subsequent geological mapping at Great Island by the MGS in

2009. The GEM initiative also provides 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.

Precambrian mapping and mineral deposit studies

Far north

The MGS's three-year study of the Hearne craton margin in Manitoba (Far North Geomapping Initiative, 2008–2011) is being undertaken in conjunction with the GSC's GEM program (Anderson et al., GS-1). This mapping, supported by sensitive high-resolution ion microprobe (SHRIMP) and isotope dilution–thermal ionization mass spectrometry (ID-TIMS) U-Pb geochronology (Rayner, GS-2), has fundamentally advanced our understanding of the complex nature, protracted evolution and diverse mineral potential of the southeastern Hearne craton margin. Of particular importance for regional tectonic correlations and mineral exploration is a new chronology of four sedimentary sequences, including a conglomerate with uranium–gold–rare earth element mineralization now recognized as a Neoproterozoic sedimentary sequence. The revised stratigraphy and map provide a solid framework for mineral exploration and are key to resolving fundamental questions pertaining to the Precambrian geology and mineral potential of Manitoba's underexplored far northeast.

An MGS collaboration with the GSC and University of Waterloo to investigate the surficial geology in northern Manitoba (Trommelen et al., GS-3) is another component of the Far North Geomapping Initiative. These surficial geological studies aim to provide a detailed framework for the directions, timing and nature of major and minor ice-flow events in the region; dispersal-train patterns as measures for ice transport distances and directions; and guidelines for the best sampling media for geochemical analysis. The outcomes of these studies are geared toward providing mineral-exploration geologists with an up-to-date surficial-geology knowledge base and the tools to more accurately locate exploration targets in Manitoba's far north. In 2010, this study was conducted throughout an 8100 km² area that extends from south of the Seal River in the Great Island area to Kellas Lake in the north. Additionally, Rogen moraine and streamlined terrain regions were mapped and sampled throughout the study area. Shallow shear-wave seismic-reflection surveys were used

to investigate the internal structure of the Rogen moraine ridges.

Also in the far north, bedrock geological mapping was undertaken in the Misty Lake area north of Lac Brochet (Kremer et al., GS-4) to examine the southwestern margin of the Hearne craton and its Paleoproterozoic cover sequence(s). Archean and Paleoproterozoic basement rocks underlying the Athabasca Basin in Saskatchewan, which locally host basement uranium deposits, are exposed at surface in the Misty Lake area. The Misty Lake area occupies the northeastern termination of a structural dome (cored by Archean leucotonalite to granite) and bounded by highly deformed metasedimentary rocks of the Wollaston Supergroup. Areas of moderate to intense alkali metasomatism occur in metasedimentary rocks and granitic rocks, in association with a variety of intrusion-hosted and metasomatic U, rare earth element (REE) and rare element mineral deposits.

The second part of a two-year community mapping program in 2010 continued to build on an information-sharing relationship between First Nation communities and the MGS (Murphy and Carlson, GS-5). The project in Tadoule Lake provides the participants with basic skills needed to work in a mineral-exploration camp and fosters awareness of geology and land-use opportunities in Manitoba's far north. Two MGS staff geologists and four members of the Sayisi Dene First Nation partnered to map and assess the quarry potential of a marble occurrence in the Ryan Lake area. The 'Dene-Tzi marble' represents an opportunity for the Sayisi Dene First Nation to develop and promote a part of their traditional land and fill a commercial niche.

Flin Flon–Snow Lake greenstone belt

In 2010, work continued on compiling the bedrock geology for the sub-Phanerozoic portion of the Flin Flon Belt (Simard et al., GS-6). Recent exploration activity has focused on the southern extension of the Flin Flon Belt under the Phanerozoic cover. Although all volcanogenic massive sulphide (VMS) deposits found to date in the exposed portion of the Flin Flon Belt are solely located within the juvenile, 1.90–1.89 Ga arc-volcanic rocks, this new work provides evidence for a younger, prospective, ca. 1.87 Ga back-arc basin of 'successor-arc' age in the eastern portion of the belt, as well as prospective tholeiitic to transitional oceanic-arc environments farther west. Results of this ongoing study provide integrated and modern exploration models for the hidden VMS deposits in covered portions of the belt.

During the summer of 2010, additional geological mapping was conducted in the northern portion of the Snow Lake–Squall Lake–Herblet Lake area (Gagné, GS-10). The resulting map, at 1:20 000 scale, includes new geological mapping and integrates results from 2008 and 2009 mapping programs. A new and updated geological

map of this area will help to establish more precisely the geometry of the various lithological units and the location of major structures, which will in turn provide important constraints for gold-exploration models. Improved knowledge of the volcanic stratigraphy will also assist when testing the various structural models to explain the internal geometry of the McLeod Road thrust panel. Finally, the results of this detailed structural analysis will help constrain the timing of gold emplacement and the deposit-scale controls on gold mineralization.

The results of geological mapping in the northern part of the Flin Flon Belt are in preparation for publication (Gilbert, GS-7). A new 1:30 000 scale map will be accompanied by notes containing descriptions of the geology and geochemistry of the various tectonostratigraphic components.

Researchers from Laurentian University initiated a study of superbly exposed regolith occurrences at Flin Flon that formed during subaerial weathering ca. 1.85 Ga (Babechuk and Kamber, GS-8). One of the best preserved regolith exposures was mapped and sampled in the summer of 2010 to guide sampling for high-precision geochemical analysis. This study will contribute to our understanding of the timing at which the atmospheric oxygen fugacity reached sufficiently high levels to result in, for example, wholesale uranium mobility during oxidative weathering.

A researcher from Mount Royal University (DeWolfe, GS-9) continued work begun in 2009 on the past-producing Schist Lake and Mandy deposits, approximately 4 km southeast of the town of Flin Flon. Detailed mapping of the strata that structurally overlie the hostrocks of the Schist Lake and Mandy deposits was the focus of fieldwork during the summer of 2010. The various volcanic facies and their lateral and vertical distributions suggest that a synvolcanic structure is present in the rocks structurally overlying the Schist and Mandy deposits, raising the possibility that these overlying rocks may also be prospective for volcanic-hosted Cu-Zn mineralization.

Thompson Nickel Belt–Superior Boundary Zone

Geological mapping of the Paint Lake area was completed in June 2010 with mapping at the north end of the lake (Couëslan and Martins, GS-11). The area is largely underlain by multicomponent gneiss, but trace-element and Sm-Nd isotope geochemistry of local metapsammite and metagreywacke suggests these supracrustal rocks are not correlative with the Ni-hosting Paleoproterozoic Ospwagan Group. A zone of previously recognized carbonatite magmatism and associated metasomatism was extended in 2010 northward into the Grass River area and now has a strike length of 23 km. Post-orogenic-type carbonatite bodies, similar to those at Paint Lake, are associated with some of the largest rare earth element deposits

in the world; however, no zones of rare earth element mineralization have been identified to date.

Superior Province

Fieldwork conducted during the summer of 2010 was designed to take advantage of a well-exposed corridor in the Family–Fishing lakes area, including the Horseshoe Lake greenstone belt (Corkery et al., GS-12). The goals of the program were to re-examine the rock types described in previous reports dating to the late 1960s and early 1970s, and to determine their geochemical, geochronological and isotopic characteristics. The new dataset will provide a consistent legend of rock types in the Berens River Domain for use in the 1:250 000 scale digital map of Manitoba. The region has economic significance because the Horseshoe Lake greenstone belt remains the only sizeable greenstone belt in the province that has never been systematically mapped.

University of Manitoba researchers conducted mineralogical, geochemical and petrographic work on samples from the Cinder Lake alkaline intrusive complex, just west of Knee Lake (Kressall et al., GS-13). This work indicates that the various rock types found in the complex form a continuous petrographic series that likely represents metasomatic reworking of a feldspathoid rock. Rare earth enrichment in some samples appears to be related to metasomatism associated with emplacement of calcite veins, possibly related to the intrusion of a carbonatite body at Cinder Lake.

Phanerozoic investigations

A new collaborative study by the Canadian Fossil Discovery Centre (in Morden, Manitoba) and the MGS aims to use fossil pollen and spores to correlate the bentonite horizons within the Pembina Member of the Pierre Shale over a long geographic distance along the Manitoba Escarpment (Hatcher and Bamburak, GS-16). These data will be used as a control to study vertebrate fossils within their respective stratigraphic horizons, and could also be used to locate the thickest bentonite seam with the highest economic value within a 5 m thick assemblage of interbedded black shale and bentonite.

Geochemical analysis of the Gammon Ferruginous Member of the Cretaceous Pierre Shale shows that this member has relatively anomalous concentrations of REE, as well as Pt, Pd, Cu, Ni, V and Zn, compared with other Cretaceous shale horizons (Bamburak and Nicolas, GS-15). Additional inorganic chemical and heavy-mineral analyses of outcrop and oilwell chip samples from the Gammon Ferruginous Member may lead to the discovery of a new, economic sedimentary deposit-type in Manitoba.

Shallow Unconventional Shale Gas Project

The economic potential for shale gas production from the Cretaceous shale sequences in southwestern Manitoba is considerable (Nicolas et al., GS-14). To date, the MGS has provided some of the basic information needed to evaluate Manitoba's shale gas prospect. To further quantify characteristics of shale sequences in southwestern Manitoba and their potential to host shallow unconventional shale gas resources, samples were collected in 2009 and sent for organic and inorganic geochemical analysis, and bulk mineralogical analysis. In addition, the microporosity and mineralogy of the Babcock beds, a 2 m thick siltstone interval in the Boyne Member of the Carlile Formation, were evaluated using scanning electron microscopy and petrography. Pore characteristics and porosity values are comparable to those of other shale gas reservoirs, such as the Barnett Shale in Texas.

Hudson Bay Basin

The Hudson Bay and Foxe basins project is in its second year (Nicolas and Lavoie, GS-17). This project is part of the GSC's Geo-mapping for Energy and Minerals (GEM) program, whose energy side aims to study the hydrocarbon potential of Phanerozoic sedimentary basins. A modern synthesis and understanding of the architecture and nature of potential hydrocarbon systems of the Hudson Bay and Foxe basins aims to promote hydrocarbon exploration in this region. In Manitoba, the Hudson Bay Basin is represented by the Paleozoic carbonate succession of the Hudson Bay Lowland in the northeastern corner of the province. An improved understanding of the stratigraphy of the Hudson Bay Lowland and how it correlates and changes across the basin is critical in understanding the geological evolution and, in turn, the economic potential of the Hudson Bay Basin.

Three-dimensional geological mapping

Manitoba plays an active and leading role as a contributor to local, national and international three-dimensional (3-D) modelling projects. Completion of a 3-D geological model of the Phanerozoic succession in southern Manitoba, south of latitude 55°N and west of longitude 95°W, is progressing (numerous cross-sections have been printed and interpreted). Increasing demands for groundwater and hydrocarbons have been the two main drivers for the 3-D mapping in Manitoba. The 3-D models unite disparate datasets and put them into a single standardized nomenclature, contributing to a variety of geoscience knowledge bases relevant to Phanerozoic stratigraphy; hydrocarbon, groundwater and industrial-mineral resource development; and geological education. Programs such as the cross-border 3-D geological mapping of the Red River Valley assist in groundwater management at large scales on both sides of the Canada–United States border.

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 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 2010–2011 included one Post-Doctoral Fellow, two Ph.D. candidates, two M.Sc. candidates and one Honours B.Sc. 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. The database summarizes all of the information contained in the reports of the Mineral Deposit Series.

Work is continuing on the second phase of data entry, the incorporation of recently released work in assessment files. In addition, mineral occurrences not covered in the original Mineral Deposit Series are being added to the database. The updates from the past year will be added to the GIS Map Gallery in a November 2010 release. The process of adding both new occurrences and updating existing occurrences with files that become nonconfidential will be a continuing process.

Geoscience Information Services

In 2009–2010, Geoscience Information Services continued support for production of the TGI-3 Flin Flon compilation map. With completion and printing of the final map, geological work in the region has shifted to compilation of sub-Phanerozoic Precambrian geology. Geoscience Information Services support is a critical component of this project because of the large number of drillhole descriptions and chemical analyses that need to be compiled. The MGS has undertaken design and production of a database system to be used in both Manitoba and Saskatchewan for compiling drill logs and assay data. This database will feed data to 3-D drillhole-mapping software.

The Far North Geomapping Initiative has required substantial support from Geoscience Information Services in terms of analysis, compilation and map production. Digital field-data collection systems required technical support from Geoscience Information Services staff, both before and after the field-mapping programs.

The geophysical dataset compilation project involves geophysical data in the nonconfidential assessment files. 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 standard projection and datum. The compilation now contains 162 airborne geophysical surveys. These data

presentations are available for free download from the GIS Map Gallery.

Production of digital geological compilation maps continued through the year with the majority of the work focused on refinement of the seamless 1:250 000 scale 'Geology of Manitoba' map compilation that was first displayed in 2009.

Client Services and Outreach

In 2009–2010, the MGS published the annual *Report of Activities*, two open file reports, three geoscientific presentations, two geoscientific maps, one stratigraphic map, five preliminary maps, four data repository items and eight digital re-releases. Most of the publications continue to be offered in hard copy, on CD-ROM or DVD for purchase through Publication Sales, and in electronic format for free download via the Internet.

New online content published by MGS in 2009–2010 includes the following:

- **Geological Survey Activity Tracker:** provides quick and easy access to information on survey projects conducted throughout the province, with an interactive map being used to ascertain project details and results
- **TGI-3 Flin Flon project site:** provides an overview of the project and its products, free PDF downloads of workshop talks and abstracts, a bibliography of related publications, and links to relevant federal and provincial data sources
- **Manitoba Precambrian Drillcore Libraries:** provides an overview of MGS drillcore facilities, with access and usage information

Manitoba Geological Survey mineral-education outreach initiatives included the 'Manitoba Rocks!' program, which was delivered at the Manitoba Mining and Minerals Convention, at the Children's Hospital and during Provincial Mining Week, which drew more than 2100 visitors. 'Manitoba Rocks!' offers free hands-on activities developed to complement the Earth-sciences curriculum and increase public awareness of the importance of Manitoba's mineral resources and mining industry.

Other MGS outreach programs included the following:

- **6th Annual Aboriginal Mining Workshop:** Held as part of the 2009 Manitoba Mining and Minerals Convention, this workshop drew more than 240 participants to discuss mining issues and opportunities with Aboriginal leaders and industry experts.
- **PDAC Mining Matters program:** The MGS helped adapt the program's curriculum-based teacher resource kits for Manitoba's geology and mineral resources, and provided the venue during Provincial Mining Week to announce the launch of the program in Manitoba.

- **Provincial Engineering and Geoscience Week:** Staff of the MGS co-ordinated interactive mineral-education displays for this annual event.
- The second year of the **Geological Mapping Course** at Tadoule Lake was discussed above (Murphy and Carlson, GS-5).
- **Canadian Aboriginal Minerals Association 18th Annual Conference:** The MGS outreach co-ordinator assisted organizers of the 2010 conference, which was held for the first time in Manitoba, on November 7–9.

Acknowledgments

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