

Annual review by E.C. Syme

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In 2009, the Manitoba Geological Survey (MGS) entered a period of transition as multiyear collaborative programming with the Geological Survey of Canada (GSC) began winding down at Flin Flon, while ramping up in the Far North and Hudson Bay Basin. To address our capacity to take on new challenges, four new full-time and term staff were hired to replace staff members who retired in recent years.

The MGS continued multiyear collaborative projects in the Paleoproterozoic Flin Flon Belt, the Northeast Kiseynew subdomain and Southern Indian Lake region, as part of the federal-provincial Flin Flon Targeted Geoscience Initiative (TGI-3; 2005–2010). Work continued in the Snow Lake area and the Thompson Nickel Belt (TNB), building on work started in 2008. New in 2009 was a major field effort in the Great Island area, west of Churchill; this was supported in part by the Geological Survey of Canada (GSC) Geo-mapping for Energy and Minerals (GEM; 2008–2013) program.

Phanerozoic investigations focused on evaluation of shallow unconventional Cretaceous shale gas potential in southwestern Manitoba, three-dimensional geological modelling in southern Manitoba and a new GEM project in the Hudson Bay Basin.

Collaborative programming with the Geological Survey of Canada

The Targeted Geoscience Initiative (TGI) announced in the February 2005 federal budget is the third in a series of such initiatives since 2000. Targeted Geoscience Initiative 3 (TGI-3) started April 1, 2005 and ends March 31, 2010, providing a vehicle to partner with the GSC on priority projects aimed at improving the economic sustainability of mining towns in north-central Manitoba. The TGI-3 Flin Flon project is an integrated, multidisciplinary geoscience study to aid in the discovery of new reserves of base metals in the region encompassed by Flin Flon–Creighton, Thompson, Leaf Rapids, Lynn Lake and La Ronge. The project has been developed through joint provincial-federal-industry consultation and is delivered as a fully integrated partnership that includes the minerals industry; researchers from Canadian and American universities; and geologists from the MGS, the Saskatchewan Geological Survey and the GSC.

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, with funding directed mostly (at

least 75%) north of 60°N. 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. A GEM-Energy project, currently in beginning stages, is focused on the Phanerozoic stratigraphy of the Hudson Bay and Foxe basins.

Precambrian mapping and mineral deposit studies

Flin Flon–Snow Lake greenstone belt

A new 1:10 000 scale bedrock geological map for Flin Flon has been completed (Simard and MacLachlan, GS-1), one of the many significant outcomes from the Flin Flon TGI-3 project involving participants from the MGS, Saskatchewan Geological Survey, GSC, Laurentian University and Hudson Bay Exploration and Development Company Limited. A coherent lithostratigraphic and structural framework now spans the provincial border; this work, supported by new structural and geochronological studies, has resulted in the recognition of the mine stratigraphy well beyond the immediate mine surroundings and has identified potentially prospective ground for exploration. New geochronological data provide additional tools for evaluating the prospectivity of contemporaneous but previously unexplored successions near Flin Flon. The ability to map and recognize volcanic subsidence structures has proven essential for exploring for volcanogenic massive sulphide (VMS) deposits in and around Flin Flon, and will be applicable to greenstone belts elsewhere in Manitoba and Saskatchewan.

As part of TGI-3, the MGS has initiated a new mapping project in the sub-Phanerozoic portion of the Flin Flon Belt (Simard and McGregor, GS-2). The main objectives are to produce a set of revised geological maps for the sub-Phanerozoic geology of the Flin Flon Belt and better define the various domains using new geophysical, isotopic, geochronological and geochemical data. This multiyear project started in 2007 with the gathering and compiling of geophysical and geochemical data, which have been incorporated into a single GIS-based database. A field program was initiated in 2009 to document some of the known mineral deposits. Selected drill-holes from the Talbot, Fenton, Harmin and Moose VMS deposits were studied and sampled for whole-rock geochemical, geochronological and Sm-Nd isotope analyses. Increasing our understanding of the setting of the various known deposits in the covered part of the belt will help

in developing and tailoring exploration models in these highly prospective rocks.

Detailed mapping (1:2000 scale) of the rocks that structurally overlie the hostrocks of the Schist Lake and Mandy deposits was the focus of work during the summer of 2009 (DeWolfe, GS-3). Although the abundance of dikes is low in the study area, the abundance and volume of volcanoclastic deposits are comparable to those hosting the mineralization in the main Flin Flon camp. These rocks contain areas of patchy, strong, quartz-epidote alteration; combined with the interpreted extensional environment and volcanoclastic units, this makes the Schist Lake–Carlisle Lake rocks an environment that is prospective for undiscovered VMS-type mineralization.

Preliminary results from detailed underground mapping, surface mapping and core logging of the footwall to hangingwall hostrocks of the Trout Lake VMS deposit show that the lithological units are not repeated at the mine scale, suggesting that the overall mine stratigraphy has not been repeated by folds and faults at the mine scale (Ordóñez-Calderón, GS-4). The Trout Lake deposit exhibits different stratigraphic characteristics than the VMS deposits at Flin Flon, and likely formed in a different tectonic setting.

A geological report and 1:50 000 scale geological map of the north-central part of the Flin Flon Belt is in preparation and planned for release in 2010 (Gilbert, GS-5). Mapping began in 1986; the aim of the current compilation work is to integrate previous mapping with associated geochemical data to produce a final map accompanied by descriptions of the geology and geochemistry of the various tectonostratigraphic components.

Geological investigation of volcanic and volcanoclastic rocks east of the town of Snow Lake was carried on during the summer of 2009 (Gagné, GS-6) to complement studies begun in 2008 and to expand upon the existing 1:20 000 scale mapping. Gold mineralization is spatially associated with the McLeod Road Thrust and is commonly situated along or adjacent to lithological contacts, so establishing the geometry of the various lithological units will help to constrain gold exploration models.

Northeast Kisseynew subdomain

The MGS initiated a program of remapping parts of the Northeast Kisseynew subdomain following the GSC's discovery of Ospwagan-type supracrustal rocks within the Kisseynew Domain at Wuskwatim Lake. Detailed mapping of inliers potentially containing these economically important rocks is generally impossible due to insufficient exposure. However, the better-exposed Notigi Lake structure—three en échelon domes comprising Sickle and Burntwood group rocks—closely resembles the map pattern of inliers of Archean basement gneiss, its cover rocks and pre-Burntwood quartz monzonite plutons in the Northeast Kisseynew subdomain. The Notigi Lake structure

can therefore act as a proxy for the structure of the inliers and answer questions regarding their continuity at depth. In 2009, the MGS completed work in the Notigi-Wapisu lakes area, located along the north flank of the Kisseynew Domain (Murphy and Zwanzig, GS-7). This work was combined with stereographic analysis and a downplunge-projection technique to decipher the Notigi Lake structure (Zwanzig and Murphy, GS-8). Understanding the three-dimensional geometry of these inliers may aid exploration in the area, since the Ospwagan-type packages in the Kisseynew have, like the Ospwagan Group in the TNB, significant potential to host nickel deposits.

Lynn Lake–Leaf Rapids

New mapping was begun in 2008 in the Southern Indian Lake region as part of the Flin Flon TGI-3 project; this work was completed in 2009 (Kremer, GS-9). The Southern Indian Lake region of the Trans-Hudson Orogen has seen little mineral exploration and was last systematically mapped in the 1960s. The purpose of the present mapping, supported by new aeromagnetic coverage funded by the GSC under TGI-3, is to re-examine the bedrock geology with particular emphasis on documenting the nature, age, tectonic affinity and mineral potential of the Pukatawakan Bay and Partridge Breast Lake areas. Temporal links are being established between volcanic rocks in the Southern Indian Lake, Rottenstone and Lynn Lake–Leaf Rapids domains, which opens the possibility for VMS-type mineralization at regional scale. The work conducted in the Southern Indian Lake area has identified a variety of mineral exploration targets in the area.

Thompson Nickel Belt

Remapping the bedrock geology in the Paint Lake area was initiated in 2008 and continued in 2009 (Couëslan, GS-10), some 30 years after the last mapping projects in the late 1970s. This new work is being conducted with the purpose of improving the understanding of the Archean basement to the TNB, and has identified both a package of potentially Archean metasedimentary rocks and a swarm of carbonatite dikes. In the TNB, ultramafic bodies intruded into Paleoproterozoic Ospwagan Group metasedimentary rocks have greater potential for forming magmatic nickel deposits than ultramafic bodies hosted by Archean gneiss. The recognition of Archean supracrustal rocks in some portions of the TNB basement that have similarities to the Ospwagan Group presents an additional complicating factor in an area already made challenging for mineral exploration by the intense deformation and high metamorphic grade.

A swarm of subparallel, steeply dipping carbonate dikes is exposed on numerous small islands in the central part of Paint Lake (Chakhmouradian et al., GS-11). This swarm of narrow discontinuous dikes has been traced over a distance of 21 km and is generally conformable to the

regional structure. The dikes are interpreted as calcite carbonatite of postorogenic affinity and point to the potential for additional magmatic and hydrothermal deposit types in the region. Carbonatites and related rocks are important sources of Nb, Fe, P and rare earth elements.

Great Island–Seal River

The MGS's three-year study of the Hearne craton margin in Manitoba (Far North Geomapping Initiative) is being undertaken in conjunction with the GSC GEM program (Anderson et al., GS-13). The Great Island area was last mapped in 1974–1975 and was chosen for further study because it provides key exposures of metasedimentary cover successions, includes the only known exposures of metavolcanic rocks in Manitoba's far north, and contains several important mineral occurrences. This area is therefore considered to be key to resolving several fundamental questions pertaining to the Precambrian geology and mineral potential of northern Manitoba. Although bedrock exposure in this area is generally very low, a significant upgrade of the existing geological map has been achieved by integrating the results of the 2009 mapping program with newly acquired aeromagnetic data.

The MGS initiated collaboration with the University of Waterloo to investigate the surficial geology in northern Manitoba (Trommelen and Ross, GS-14) as part of the Far North Geomapping Initiative. Preliminary results from a two-week reconnaissance survey in 2009 provide new constraints to drift exploration in this area, applicable to exploration for a variety of commodity types, including diamonds, precious metals and gold. 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 the summer of 2009, the MGS conducted a two-week geological mapping course with the Sayisi Dene First Nation at Tadoule Lake (Murphy and Carlson, GS-15). The goals of the program were to help increase awareness of the region's geology and mineral resources, provide the basic skills needed to work in a mineral exploration camp, and foster information sharing between First Nation communities and the MGS. Four members of the community were hired as student-trainees and three completed the first half of the program; one of the trainees was hired by the MGS as a field assistant in the Seal River–Great Island area. Plans are for a second two-week course to be delivered in Tadoule Lake in 2010.

Phanerozoic investigations

Hudson Bay Basin

The hydrocarbon potential of the Hudson Bay and Foxe basins is being studied as part of the GSC's GEM-Energy program. A better understanding and a modern

synthesis of the geoscience and hydrocarbon systems of these basins aims to encourage industry to consider this region for future hydrocarbon exploration. 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 (Nicolas and Lavoie, GS-16). Existing geoscientific data are being re-evaluated using modern ideas and new scientific technologies, and new data will be acquired in areas currently presenting knowledge gaps. Although the offshore Hudson Bay Basin is outside Manitoba's jurisdiction, the only deep-water port in these northern waters is located in Churchill. Any exploration activities and resulting hydrocarbon production, development and related infrastructure would provide significant economic growth and stimulus for northern Manitoba.

Shallow Unconventional Shale Gas Project

Shallow shale gas occurrences have been recorded in Manitoba for more than a century, but there are limited geoscientific data that would assist in understanding the resource potential. The goal of this four-year project is to summarize the shallow shale gas prospects for Manitoba, characterize the gas, define the area of gas occurrence, and identify intervals with prospective formations with the greatest potential to contain gas.

Laboratory results from sampling conducted in 2008 are encouraging (Nicolas and Bamburak, GS-17). The combination of shale with thick siltstone and sandstone beds, documented gas shows, favourable organic geochemistry and high quartz fractions within the Boyne Member of the Carlile Formation indicate that Manitoba has the right geological conditions for the generation of unconventional shallow gas of biogenic origin. Fieldwork during the 2009 field season focused on collecting samples from the northern part of the study area, particularly in the Riding Mountain, Swan River valley, Duck Mountain and Porcupine Hills regions.

Water and gas chemistry of the Cretaceous shale aquifers and gas reservoirs of the Pembina Hills area in southwestern Manitoba were analyzed (Nicolas and Grasby, GS-18). Chemistry and stable-isotope results indicate that accumulations of biogenic natural gas are present in this area. Stratigraphic extrapolations of the water- and gas-well data suggest that the Assiniboine Member of the Favel Formation and the Boyne Member of the Carlile Formation are the horizons with known gas accumulations.

The Mobile Metal Ion (MMI®) surficial geochemical technology was evaluated as an exploration tool in the search for unconventional shallow shale gas reservoirs (Fedikow et al., GS-20). An orientation survey was conducted to assess the potential for partial extractable geochemical signatures associated with a shallow gas vent site near Manitou. Results demonstrated that multiple

diagnostic responses for certain elements are present in the soil profile. Application of this technology opens up shallow gas exploration opportunities in southwestern Manitoba.

A re-evaluation of Cretaceous stratigraphic nomenclature in Manitoba has evolved from the evaluation of shallow gas potential in Manitoba (Bamburak and Nicolas, GS-19). Correlation of Cretaceous formations, members and beds to equivalent units in other provinces and states in North America has resulted in numerous changes to Manitoba's stratigraphic terminology through time. Understanding the evolution of these changes provides exploration opportunities for potential natural gas resources in Manitoba. With new technologies and applications available to study sedimentary basins in more detail than ever before, understanding the currently accepted stratigraphic framework is crucial in the search for new natural gas resources.

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 (Keller et al., GS-21). Increasing demand 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.

Other projects

University of Manitoba researchers continued with a program investigating the revegetation of mine tailings (Young et al., GS-12). The mine tailings deposited during operation of the Gunnar gold mine have remained largely nonvegetated since the mine was closed 67 years ago. Based on a modest dollar value for carbon storage, the ability of this site to hold on the order of 3000 tonnes of carbon represents a significant economic potential.

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 2009–2010 included one Post-Doctoral Fellow, one Ph.D. candidate, two M.Sc. candidates and three Honours B.Sc. thesis projects.

Mineral deposits database

The digital mineral deposits and occurrence database for Manitoba has been available on the Web in MGS GIS Map Gallery site 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 nonconfidential work in assessment files. In addition, mineral occurrences not covered in the original Mineral Deposit Series are being added to the database. These updates will be added to the GIS Map Gallery in a November 2009 release. An important addition is in the far north, where more than 200 new records have been entered.

The process of adding both new occurrences and updating existing occurrences with files that become nonconfidential will be a continuing process. Importantly, more than 50 years of data from the Fox River Belt will be entered into the database during the last quarter of 2009–2010.

Geoscience Information Services

Considerable effort in 2009 was devoted to supporting ongoing compilation at 1:5000 and 1:2000 scales in the Flin Flon Belt. As well as cartographic support in producing the final compilation, considerable effort was devoted to compiling and merging open file geophysical datasets for the Flin Flon–Snow Lake region in support of the Flin Flon compilation and the ongoing sub-Phanerozoic compilation program.

The Williston Basin TGI-2 project is nearing completion, using a standardized database to combine Manitoba and Saskatchewan data. Work continued through 2009 on finalizing databases and producing new versions of maps for the entire stratigraphic section. A digital compilation of hydrocarbon assessment information was completed and released in the spring of 2009. Release of the final version of the master stratigraphic database is the only item outstanding from this program.

The production of a seamless 1:250 000 scale digital geological base (version 1) map for Manitoba is complete. The dataset has been integrated into the Minerals Division GIS Map Gallery and is now available on the website.

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. New additions to the

system make the holdings current to 2009. These data presentations are available for free download from the GIS Map Gallery.

Client Services and Outreach

In 2008–2009, the MGS published the annual *Report of Activities*, 2 open file reports, 136 open file maps (aeromagnetic survey maps published in collaboration with the Geological Survey of Canada), 1 geoscientific report, 1 geoscientific paper, 6 preliminary maps, 39 stratigraphic maps and 4 data repository items. 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 Web.

New Web content published by MGS in 2008–2009 included

- 1) the Williston Basin ‘Hydrocarbon Assessment Compilation’, a GIS compilation of oil and gas showings, wells, field and pool boundaries with geological base, and a 3-D geological model of the Williston Basin, all of which were added to the TGI-2 Williston Basin Architecture and Hydrocarbon Potential Project site;
- 2) the Mineral Deposits Database (discussed above); and
- 3) MGS Geoscience Projects 2009–2010, an overview of the survey’s programs as presented to the Mineral Exploration Liaison Committee at an annual Geoscience Review meeting hosted by the MGS.

Manitoba Geological Survey mineral-education outreach initiatives included the ‘Manitoba Rocks!’ program, which was delivered at the Manitoba Mining and Minerals Convention, Children’s Hospital and during Provincial Mining Week, which drew more than 4,000 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:

- **5th Annual Aboriginal Mining Workshop:** Held as part of the 2008 Manitoba Mining and Minerals Convention, this workshop drew the highest attendance to date, with more than 158 participants.
- **4th Annual Learning Together Conference:** The conference this year focused on how industry and communities can move forward to mutually benefit from mineral development.
- **The Geological Mapping Course** at Tadoule Lake was discussed above (Murphy and Carlson, GS-15).
- **Sosnowski Lake camp assistants:** To provide local training and employment opportunities, the MGS hired three camp assistants from the Sayisi Dene First Nation community at Tadoule Lake.
- **Manitoba Ranger Program, 2009:** An MGS geologist assisted in the five-week employment and training experience for students aged 16–18. The program provides career awareness and work experience in the northern resource sectors of mining, forestry and energy.
- **Provincial Engineering and Geoscience Week:** Staff of the MGS co-ordinated interactive mineral-education displays for this annual event.
- In addition, staff attended Aboriginal conferences, such as Vision Quest and the Canadian Aboriginal Minerals Association Conference.

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