

Annual review by E.C. Syme

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Introduction

In 2007, the Manitoba Geological Survey (MGS) continued multiyear programs in the northern Superior Province, the Paleoproterozoic Flin Flon Belt, the eastern Kiseeynew Domain and Thompson Nickel Belt (TNB), and the Bissett and Bird River regions of southeastern Manitoba. Phanerozoic investigations focused on posting new Williston Basin Targeted Geoscience Initiative (TGI) content to the project's website, expanding the study of the Devonian Three Forks Formation and completing the Surficial Geology Compilation Map Series.

New field projects were initiated in

- the northern Superior Province, at Utik Lake, as the second year of a multiyear project aimed at updating the bedrock mapping database for greenstone belts in the region; and
- the Notigi Lake area, as a contribution to the Targeted Geoscience Initiative III (TGI-3).

Targeted Geoscience Initiative

A significant portion of MGS work in 2007 was conducted as part of the Targeted Geoscience Initiative (TGI). This initiative provides a vehicle to partner with the Geological Survey of Canada (GSC) on priority projects aimed at improving the economic sustainability of mining towns in northern Manitoba. The current TGI, announced in the February 2005 federal budget, is the third in a series of such initiatives since 2000. Federal funding for TGI-3 is \$25 million (nationally), to be spent over a five-year period that started April 1, 2005.

The TGI-3 Flin Flon project is an integrated, multidisciplinary geoscience study to aid in the discovery of new reserves of base metals in established mining communities of west-central Manitoba and east-central Saskatchewan. 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 (SGS) and the GSC.

Individual MGS projects associated with TGI-3 are described separately in subsequent sections. Those components of the Flin Flon project funded by the GSC that were conducted in or adjacent to Manitoba and are not reported in this volume include

- collection and subsequent analysis of approximately 45 km of two-dimensional (2-D) seismic profile data at Flin Flon; in addition, Hudson Bay Exploration and Development Co. Ltd. has separately contracted additional 2-D profiles and a 3-D seismic survey at

Flin Flon;

- a high-resolution aeromagnetic survey in the eastern Kiseeynew Domain area, building on a 2006 survey on the west flank of the Thompson Nickel Belt;
- Quaternary mapping and sampling in the Sherridon, Snow Lake and eastern Kiseeynew Domain areas;
- borehole-geophysical-data processing (rock property data) as an input into the seismic studies subproject; and
- detailed mapping at Flin Flon by researchers and graduate students at Laurentian University.

Precambrian mapping

Flin Flon–Snow Lake greenstone belt

As part of the MGS contribution to TGI-3, metavolcanic rocks in the Flin Flon area were mapped at 1:5000 scale, including (in Manitoba) the northern part of Schist Lake–Mandy Road area, the Hidden Lake syncline area and part of the Hook Lake Block (Simard and Creaser, GS-1). Using a combination of detailed volcanic facies analysis, structural mapping and geochemical characterization of each unit in the area, this mapping has extended the recently established Flin Flon–Callinan–Triple 7 mine stratigraphy from the Flin Flon mine area south to Schist Lake. Uncertainties remain because the proximal volcanic arc environments characteristic of Flin Flon are highly complex due to multiple volcanic centres, local subsidence structures and the episodic nature of volcanism. Work is currently underway to better understand the structural evolution of the immediate Flin Flon area and to define the timing and geometry of the multiple deformation events and their effect on the distribution of mine stratigraphy. New and previous mapping in the Flin Flon area has been compiled and assembled into a 1:10 000 scale cross-border map to be published as part of the TGI-3 project.

As a contribution to the Flin Flon 1:10 000 compilation, detailed mapping was also conducted in the Hook Lake Block (Kremer and Simard, GS-2). This area contains a comparatively unique volcanic and volcanoclastic stratigraphy with respect to the Flin Flon Block to the west. The mapping has highlighted many similarities between Hook Lake Block rocks and those of the neighbouring Flin Flon Block: both contain volcanic stratigraphy displaying significant subsidence or basin structures, with associated felsic volcanism and VMS-type mineralization. However, a direct correlation between the stratigraphy of the Hook Lake Block and that of the Flin Flon Block is premature.

Laurentian University researchers H. Gibson and B. Lafrance, together with graduate students E. Cole, D. Lewis and M. DeWolfe, continued detailed mapping in the footwall and hangingwall rocks of the Flin Flon, Callinan and Triple 7 deposits. A two-year research project to characterize and describe the Schist Lake–Mandy Road volcanogenic massive sulphide deposits and their hostrocks was started in 2007 by one of the Laurentian graduate students (Cole and Gibson, GS-3). The Schist Lake and Mandy deposits were the first to be mined in the Flin Flon area, but their stratigraphic relationship to the other Flin Flon Cu-Zn deposits is still not established. Preliminary results suggest that the Schist Lake orebody and host strata were dismembered by a shear zone.

East Kiseynew–Superior Boundary Zone–Thompson Nickel Belt

The MGS and partners in the GSC continued a multi-year program, within TGI-3, aimed at defining the geographic extent of TNB-type inliers within what is currently mapped as younger Burntwood Group metaturbidite rocks in the northeastern Kiseynew Domain. Exciting and unexpected results from detailed mapping, isotopic and geochronological investigations have shown that Archean basement, together with an autochthonous cover sequence, occur in this part of the Kiseynew Domain. The origin, structure and extent of these older rocks in the predominantly greywacke-derived migmatite of the northeastern Kiseynew Domain are still poorly understood. This work has clear implications for nickel exploration, opening up new areas for consideration that would have been disregarded only five years ago.

New mapping was undertaken in 2007 at Notigi Lake, on the north flank of the Kiseynew Domain northwest of Thompson (Murphy and Zwanzig, GS-5). The study area represents an example of the stratigraphic and structural relationships of the Paleoproterozoic Burntwood and Sickle groups, as well as a prominent amphibolite that is reinterpreted as volcanic in origin and may mark a regional crustal suture. Previous geological investigations have been updated using new structural data and analysis, as well as lithological subdivision of the Sickle Group. The structural style of the Notigi Lake area may serve as a guide to determine the structural style and 3-D extent of the Archean and Oswagan-like rocks in the Kiseynew Domain.

Fieldwork was conducted during the summers of 2006 and 2007 in the Kawaweyak Lake area of the northeasternmost Kiseynew Domain to determine the provenance of potentially Oswagan Group–equivalent rocks. A sample of semipelite has yielded a Nd model age inconsistent with an affinity for the Oswagan Group but similar to either the juvenile Paleoproterozoic Burntwood Group or an assemblage of amphibolite and siliciclastic rocks that generally overlies the Burntwood Group.

Work led by the GSC in the northeastern Kiseynew

Domain (Percival et al., GS-7) as part of the TGI-3 project aims to delimit the distribution of Archean basement and Oswagan Group–like supracrustal rocks within what is currently depicted as Burntwood Group metasedimentary rocks. The occurrence of pre-Burntwood intrusions as far west as Atik Lake suggests that basement complex rocks occur widely beneath the region. Although these rocks could potentially host Thompson-type deposits, their prospectivity would be limited except near exposed structural culminations.

Geochronological results from proposed Archean inliers within the Kiseynew Domain (Rayner and Percival, GS-8) provide further evidence of Archean basement rocks underlying the northeastern quadrant of the Kiseynew Domain. Although a definitive correlation has not been made between Oswagan-type supracrustal rocks within the Kiseynew Domain and Oswagan Group rocks within the TNB, the potential for Thompson-type nickel mineralization is still present. The lithological association of basement, supracrustal rocks including iron formation, and mafic-ultramafic sills in the Wuskwatim Lake–Burntwood River area and possibly the Tullibee–Neuls lakes area is similar with those observed in the TNB.

Within the Thompson Nickel Belt proper, the objective of a continuing Ph.D. study on regional metamorphism is to better understand the tectonic evolution of the belt (Couëslan et al., GS-9). Documenting the Oswagan Group at various metamorphic grades will assist in the identification of these prospective rocks during exploration programs, especially in portions of the belt that have been subjected to higher grades of metamorphism. The local grade of regional metamorphism may also significantly affect the mobilization of orebodies through solid-state, hydrothermal and anatectic processes.

Northern Superior Province

An Archean mafic metavolcanic–dominated greenstone belt at Utik Lake in central Manitoba was mapped and studied in detail (Böhm et al., GS-10) to determine the nature, age and composition of the supracrustal rocks. Work also included an analysis of the kinematics and structural evolution of the Utik Lake greenstone belt, and an assessment of the potential of the area to host volcanogenic massive sulphide and gold deposits. Together with 2006 mapping in the nearby Bear Lake area, this study will provide an improved geological context and regional framework for base- and precious-metal exploration in the northern Superior Province.

Bird River Belt

In 2005, the MGS initiated a government–industry–university partnership in the Neoarchean Bird River Belt of southeastern Manitoba. Partners in the initiative include the MGS, researchers and graduate students at

the University of Waterloo (partially funded by Gossan Resources Limited, Mustang Minerals Corp., Tantalum Mining Corporation of Canada Limited [Tanco], the university and the Natural Sciences and Engineering Research Council of Canada). The group is undertaking mapping, structural analysis and geochronological investigations in order to better understand both the evolution of the Bird River Belt and the setting of the various deposit types, and to support the exploration programs that are currently underway in the area. Work in 2007 completed the three-year project; M.Sc. students P. Kremer and C. Mealin finished their fieldwork in 2006.

Field investigations in 2007 by University of Waterloo postdoctoral fellow M. Duguet (GS-13) have highlighted the kinematic pattern of a major shear zone separating the English River Subprovince from the Bird River greenstone belt. New geochronological data on the Maskwa Batholith demonstrate that it should be considered an independent microcontinent that split off during a back-arc spreading event. Occurrences of Ni–Cu–platinum group element (PGE) mineralization in mafic-ultramafic bodies are associated with this event and are found on both sides of the Maskwa Batholith (i.e., Bird River Sill and Maskwa-Dumbarton mines to the south, and Mayville Formation to the north).

Regional and detailed stratigraphic mapping, geochemical and geochronological investigations within the Bird River greenstone belt have resulted in a revised stratigraphic framework (Gilbert, GS-12) defining predominant arc-type rocks that are tectonically distinct from flanking, older, back-arc-type basaltic sequences. The basalt sequence is intruded by the Bird River Sill. Mineralization associated with the metavolcanic rocks includes a variety of occurrences located either at lithological contacts or within stratigraphic members such as felsic volcanic rocks in the arc succession and in basalt of the back-arc succession.

Mineral deposit studies

Snow Lake

A metallogenic and metamorphic study of selected gold-bearing deposits from Snow Lake and the southern flank of the Kiseeynew Domain by McGill University Ph.D. candidate S. Gagné (GS-4) is supported by the MGS and the GSC. Investigation of sulphide-gold mineralization will provide new constraints on the timing of mineralization and a better understanding of the mineralogical and compositional consequences of mid-amphibolite-facies metamorphism on sulphide-dominated ore. The study will also increase knowledge of sulphide-silicate-oxide interaction during prograde metamorphism and help to delineate the effects of the sulphidization and oxidation halo on altered wallrock.

Southeastern Manitoba

Bedrock geological mapping in the Lily Lake area of the Rice Lake greenstone belt has improved understanding of the stratigraphy and structure of the Neoarchean Edmunds assemblage, as well as the nature and setting of its contained gold occurrences (Anderson, GS-11). The most significant gold occurrences are hosted by a distinctive association of rock types and are spatially associated within a deformation corridor. These occurrences are strongly analogous to epigenetic gold deposits in the Beardmore-Geraldton greenstone belt of the Superior Province and the Rankin Inlet greenstone belt of the Hearne Province. The regional tectonic setting and lithostratigraphy of the Lily Lake area are also substantially similar to those in the area of the Éléonore property in the James Bay district of Quebec.

Manitoba Mineral Deposits Database

The creation of a searchable digital mineral deposits and occurrences database for the Province of Manitoba has been a goal of the Manitoba Geological Survey for a number of years. The MGS has now completed the design of a searchable Oracle® database to replace the existing mineral deposit information that is accessed through the GIS Map Gallery. The existing Map Gallery presentation, comprising shapefiles and HTML pages derived from the Mineral Deposits Series Reports, is neither readily searchable nor complete. In the newly designed database, contained information will summarize all of the non-confidential work that has been performed on specific properties. References included in the database allow users to find additional information for occurrences.

Phanerozoic investigations

The Sedimentary and Industrial Minerals Section conducted fieldwork and office-based projects in 2007 (Bezys, GS-20). Staff capacity was significantly enhanced when M. Nicolas joined the section in spring 2007 as a stratigraphic and petroleum geologist. Much progress was made on the Williston Basin TGI project, with new content posted on the project's website. The Devonian Three Forks Formation study has been expanded to improve understanding of the formation's oil-bearing capacity. In addition to the project areas discussed below, staff have led field trips for the petroleum industry and responded to numerous requests for information on industrial minerals and aggregate deposits. Work was also conducted on the Phanerozoic lineament study and 3-D geological mapping of Manitoba, and support was provided to the Protected Areas Initiative Mining Sector Consultation and development of the mineral deposits database.

Williston Basin Targeted Geoscience Initiative

The Williston Basin TGI-2 project has shown that interprovincial subsurface correlations are invaluable

and represent a significant accomplishment. This is best demonstrated in the new stratigraphic correlation chart and database of the study area that are now available for viewing on the website (<http://www.gov.mb.ca/iedm/mrd/geo/willistontgi/index.html>). This information, together with the detailed crossborder Mesozoic correlations, will be of assistance to the petroleum exploration industry in southwestern Manitoba.

Phanerozoic stratigraphy

Three coreholes were drilled in the 2007 Stratigraphic Corehole Drilling Program (Bamburak, GS-16). One hole near Duck Bay, west of Lake Winnipegosis, penetrated what is interpreted as hydrothermally altered dolomite within the upper part of the Silurian Interlake Group, beneath the Devonian Ashern Formation. This discovery, if confirmed, would be significant because it would indicate that hydrothermal fluids have flowed through and locally altered the Paleozoic stratigraphic sequence, increasing porosity and permeability. The leached limestone and dolomite could potentially host Mississippi Valley-type Pb-Zn mineralization, explaining the sulphide mineralization found, for example, near Pemmican Island in the north basin of Lake Winnipegosis.

The discovery of the new, conventional-oil Sinclair Field in southwestern Manitoba has substantially increased Manitoba's oil reserves and coincided with the TGI crossborder correlations. New work was also conducted on the Devonian Three Forks Formation in southwestern Manitoba (Nicolas, GS-17). The Three Forks Formation hosts the Sinclair Field, with proven and probable reserves estimated at 6.8 million m³. A number of new exploration targets were identified in this study, northward and eastward of the Sinclair Field. Further study of the Devonian Three Forks Formation in Manitoba may see an expansion of the play beyond the current boundaries of the Sinclair Field.

Industrial minerals investigations

Industrial minerals potential was investigated in the Rural Municipalities of Miniota, Archie and Rosburn in southwestern Manitoba (Bamburak, GS-18). Undeveloped deposits of Souris-type gravel, swelling sodium bentonite, potash and sodium chlorate, or manganese are present in some of the rural municipalities and would help to diversify their economic base.

Surficial Geology Compilation Map Series

The Surficial Geology Compilation Map Series (SGCMS) has been completed and was released on November 15, 2007 on DVD (second edition) and as a hard copy, 1:1 000 000 scale surficial geology map. The SGCMS provides seamless, province-wide coverage of all the most current and detailed surficial geology available. These data are useful for applications such as groundwater

protection, land management and mineral exploration.

The final 1:1 000 000 scale compilation is a unique, two-sided, full-colour map that supersedes Geoscientific Map 81-1, released in 1981. The front of the new map contains 1) hill-shaded surficial geology polygons; 2) major landforms, including glacial ice-flow direction; and 3) a brief description of Manitoba's landscape. The back of the map contains 1) an innovative, graphic description of map units, including images and diagrams to define each unit in nonscientific terms; 2) an index map to locate the images; 3) a paleogeographic reconstruction of late glacial events; 4) diagrams depicting the effect of isostatic rebound on the Tyrrell Sea and lakes Winnipeg and Manitoba; and 5) a 3-D block diagram. All SGCMS products are also available for download from <http://www.gov.mb.ca/iedm/mrd/geo/gis/surfgeomap.html> in PDF and shapefile formats.

Aggregate resources

The Rural Municipality of Park was mapped this year to update aggregate information for land-use planning (Groom, GS-19). The nature of the landscape and proximity to Riding Mountain National Park have resulted in increased recreational development, which has in turn put increasing land-use pressure on aggregate deposits in some parts of the municipality. Field results suggest that the volume of aggregate in the areas of the nearby active pits is more than adequate to meet the current and projected needs, but land-use planning decisions need to take these important resources into account so they can continue to be utilized.

Other projects

Hydrological dynamics in the Winnipeg River basin

The Winnipeg River in northwestern Ontario provides nearly half of the total flow into Lake Winnipeg and the Nelson River, and is the most important component of the hydroelectric system that generates power for Manitoba. A continuing study by S. St. George (GS-14) uses a network of 54 tree-ring records to estimate changes in summer climate within the Winnipeg River basin since AD 1783. The tree-ring record indicates that summer droughts were more persistent in the 19th and late 18th centuries, but there is no evidence that drought was more extreme prior to the onset of direct monitoring. This research program has demonstrated that, unlike most regional rivers, flow in the Winnipeg River system increased during the 20th century, with most of the gains occurring between 1920 and 1960. For a longer perspective, tree-ring records from the Winnipeg River basin and the broader Prairies region have been used to estimate drought conditions in the Manitoba Hydro watershed during the last several hundred years.

Revegetation of tailings at the Gunnar minesite

University of Manitoba researchers continued with a program investigating the revegetation of mine tailings (Renault et al., GS-15). A small-scale field experiment was designed in 2007 to test the effects on plant establishment and growth of rototilling, fertilizing, microbial inoculation and amending Gunnar tailings with paper-mill sludge. Research oriented towards using readily available amendments, such as paper-mill sludge, to increase revegetation success on such sites would benefit the paper-mill and mining industries, as well as the government and future land users.

Core storage facilities

Manitoba's Mineral Resources Division has been storing Precambrian drillcore, obtained primarily from exploration drilling, since the early 1970s (GS-22). Since that time, the Manitoba government has created a substantial repository of drillcore at five locations throughout the province (Thompson, Flin Flon, Lynn Lake, The Pas, and Winnipeg).

Compilation and partnerships

The Manitoba Geological Survey is engaged in many partnered initiatives, including contributions from the federal government, the mineral industry and several Canadian universities. Partnerships added approximately \$1.4 million to geoscience programming in Manitoba for 2007–2008, and represent significant leverage of the MGS geoscience budget. The projects facilitate the training of future geoscience professionals, including in 2007 one postdoctoral fellow, two Ph.D. candidates and one M.Sc. candidate. Primary focuses for partnerships in 2007 were the Flin Flon TGI-3 project and the Bird River suite of projects.

Geoscience Information Services

The Geoscience Information Services section continues to support the operation of the Geological Survey's research activities by providing data management, GIS and graphic production services.

During 2006, more than 200 isopach and structure contour maps were produced for the Williston Basin TGI-2 project, using a standardized database combining Manitoba and Saskatchewan data. Work continued through 2007 on finalizing databases and producing maps for the upper parts of the stratigraphic section.

Recompilation and updating of existing Bedrock Geology Compilation Maps resulted in the production of a seamless 1:250 000 scale digital geological base map for Manitoba, with approximately two-thirds of the province now compiled and edge-matched.

Work on the Thompson Nickel Belt project continued in 2007, with the focus being production of a final printed map series.

The compilation of open file company geophysical

datasets has focused 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.

Geoscience Information Services has devoted considerable effort to supporting ongoing compilation at 1:5000 and 1:2000 scales in the Flin Flon Belt.

Client services and outreach

In 2006–2007, the MGS published two geoscientific reports, including the annual Report of Activities, thirteen maps, one database and two data repository items. In response to client needs, the majority of the publications were released as hard copy, CD-ROM, or DVD for purchase through Publication Sales, and in electronic format for free download via the Web.

Manitoba Geological Survey mineral-education outreach initiatives included the Manitoba Mining and Minerals Convention (MMMC) Schools Program, National Engineering and Geoscience Week, Earth Science Week and Provincial Mining Week. Twenty-seven students from Cross Lake First Nation in northern Manitoba made the trip to Winnipeg to take part in the 2006 MMC mineral education activities. Provincial Mining Week offered 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. Despite inclement weather, the outdoor event drew more than 2500 visitors. In August, the MGS partnered with the Manitoba Children's Museum for the first time to help celebrate the museum's Earth Science Week; 158 people participated in the MGS-sponsored activities.

The third annual Aboriginal Mining Workshop was held as part of the November 2006 Manitoba Mining and Minerals Convention. Eighty participants met to discuss mineral exploration and development opportunities, including training, employment, business ventures and social initiatives.

Survey staff delivered mining and geology presentations to Aboriginal communities at Fox Lake Cree Nation, Northlands First Nation and the Nelson House Resource Management Board, as well as Wolseley School, the Winnipeg Rock and Mineral Club and the Mineral Society of Manitoba. In addition, staff attended such Aboriginal conferences as Vision Quest and the Canadian Aboriginal Minerals Association.

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