

Annual review by E.C. Syme

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Introduction

In 2006, the Manitoba Geological Survey (MGS) continued significant in-depth investigations in the Superior Boundary Zone and Thompson Nickel Belt (TNB), the Paleoproterozoic Flin Flon Belt, and the Bissett and Bird River regions of southeastern Manitoba. Phanerozoic investigations focused on completing the surficial geology compilation for the province and the inception of a multi-agency Phanerozoic lineament study.

New field projects were initiated in

- the northern Superior Province, at Bear Lake, as the first year of a multiyear project aimed at updating the bedrock mapping database for greenstone belts in the region;
- the Kasmere Lake area of Manitoba's far north, with a multidisciplinary approach spanning bedrock mapping, isotope geochemistry, mineral-deposit investigations and Quaternary mapping and sampling; and
- the Wuskwatim Lake and Flin Flon areas, as contributions to the Targeted Geoscience Initiative.

Targeted Geoscience Initiative

In February 2005, the Government of Canada committed \$25 million over five years to extend the mission of the Targeted Geoscience Initiative (TGI) Program, which has included two previous programs (TGI-1 in 2000–2003 and TGI-2 in 2003–2005). These are partnership programs delivered in collaboration with provincial geological surveys and with participation by industry and universities.

The TGI-3 Flin Flon project is an integrated, multi-disciplinary geoscience study to aid in the discovery of new reserves of base metals in vulnerable, established mining communities of Manitoba and Saskatchewan (the area encompassing Flin Flon, Snow Lake, Leaf Rapids, Thompson–Wabowden (exclusive of the Thompson Nickel Belt), Lynn Lake, La Ronge and Creighton). The objective is to develop and test new geoscientific models, methods and approaches that will guide exploration in this highly prospective area of the Canadian Shield. The project has been developed through joint provincial-federal-industry consultation and will be delivered as a fully integrated tripartite partnership including the minerals industry, researchers from Laurentian and McGill universities, and geologists from MGS, the

Saskatchewan Geological Survey and the Geological Survey of Canada (GSC). The project will comprise three major subcomponents (Figure 1):

- 1) Tier One (highest priority) subcomponent will focus on base-metal-rich portions of the Glennie–Flin Flon–Snow Lake district, and will include geoscience directly related to extending existing reserves of base metals and bringing to light new occurrences in the district; subprojects include
 - a 1:10 000 bedrock map of the immediate Flin Flon area and supporting geoscience studies, including stratigraphy, volcanic architecture and structure;
 - a camp-scale 3-D 'knowledge cube', underpinned by a 2-D seismic study and subsurface geochemical, stratigraphic and structural data incorporated from existing Hudson Bay Exploration and Development Co. Ltd. drilling;
 - supporting geoscience studies in Snow Lake;
 - airborne surveys of part Saskatchewan's southern Glennie Domain (completed 2006) and northern Hanson Lake Block, and remote predictive interpretation maps based on integration of the airborne surveys with targeted new mapping; and
 - ore mineralogy, sulphide geochemistry and isotopic studies.
- 2) Tier Two (second priority) subcomponent will focus on regional Trans-Hudson Orogen base-metal potential and includes
 - magmatic Ni–platinum group element (PGE) potential, litho-geochemistry and isotopic studies of selected targets in the northern and western Lynn Lake and La Ronge greenstone belts;
 - synthesis of the surficial geology of Saskatchewan and Manitoba, including supporting till geochemical analyses, airphoto interpretation and targeted surficial mapping;
 - an airborne survey in the Wuskwatim Lake area west of Thompson (completed 2006), associated targeted field mapping and supporting isotopic and geochemical analyses, resulting in new 1:100 000 maps of the eastern Kiseynew Domain; and
 - an airborne survey in the Partridge Breast Lake area, north of Leaf Rapids, and updated bedrock geological maps of the Lynn Lake–Partridge Breast Lake area.

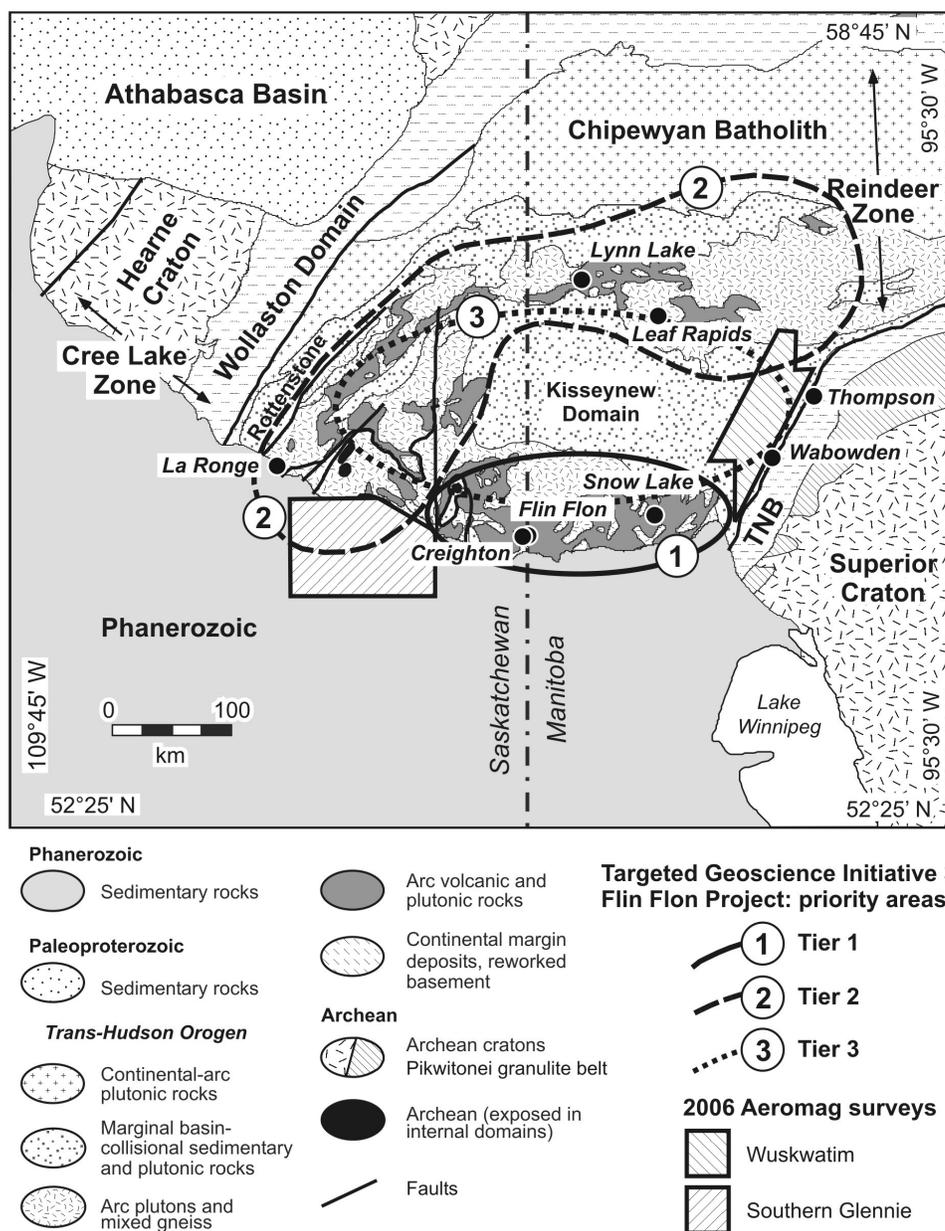


Figure 1: Targeted Geoscience Initiative areas of focus in the Flin Flon–Snow Lake–Wabowden–Thompson–Leaf Rapids–Lynn Lake–La Ronge–Creighton area of the Trans-Hudson Orogen in Manitoba and Saskatchewan.

- 3) Tier Three (lowest priority) subcomponent will focus on regional definition of iron oxide–copper–gold (IOCG) potential through fieldwork and supporting lithogeochemical and isotopic studies.

Precambrian mapping

Flin Flon–Snow Lake belt

Staff from the Manitoba, Saskatchewan and Canadian geological surveys joined researchers from Laurentian University in a group of interrelated mapping projects spanning the Manitoba–Saskatchewan border as part of the Flin Flon TGI-3 project. The centerpiece of

collaborative mapping activities is a new 1:10 000 scale ‘cross-border’ geological map of the Flin Flon area. In 2006, Renée-Luce Simard (MGS) focused on the Schist Lake–Mandy mines area, 4 km south of Flin Flon (GS-1). This new mapping allowed recognition of rocks comparable to those in the hangingwall to the Flin Flon–Callinan–Triple 7 ore deposits. Volcanogenic massive sulphide deposits in the Flin Flon area occur in association with the felsic volcanic units in synvolcanic collapse structures and calderas within the main mafic volcanic complex, so the ability to recognize these structures is crucial to exploration in and around Flin Flon.

Laurentian University researchers Harold Gibson and

Ph.D. candidate Michelle DeWolfe continued detailed mapping in the footwall and hangingwall rocks of the Flin Flon, Callinan and Triple 7 deposits (GS-2). This work is aiding in the definition of exploration targets through the development of a robust local stratigraphy, recognition of synvolcanic subsidence structures and recognition of structural repetition in the volcanic stratigraphy.

Superior Province

New work was initiated at Bear Lake in the northern Superior Province by Christian Böhm (MGS) and Russell Hartlaub (British Columbia Institute of Technology; GS-7). The Bear Lake area hosts several shear-zone-bounded panels of volcanic and sedimentary rocks at lower to middle amphibolite facies, comparable to supracrustal rocks of the Hayes River and possibly Oxford Lake groups at northern Oxford Lake and southwestern Knee Lake. Together with planned mapping in the Atik Lake area, this study will provide an improved geological context and regional framework for base and precious metal exploration in this part of the northern Superior Province.

Superior Boundary Zone and eastern Kiseynew Domain

High-resolution images from the 2006 Wuskwatim Lake aeromagnetic survey (Figure 1) were used in conjunction with new mapping by John Percival (GSC), Herman Zwanzig and Linda Murphy (MGS), and isotopic data (Nicole Rayner, GSC) to reinterpret the geology of the Kiseynew Domain west of the TNB (GS-8 and -10). The results suggest that a 60 km wide zone, previously considered to consist entirely of Paleoproterozoic Burntwood Group migmatite and granite, is structurally interleaved with heterogeneous gneiss, which resembles Superior Province basement and the lower part of its Paleoproterozoic metasedimentary cover sequence (Ospwagan Group). These units are exposed in structural culminations, suggesting they are widely distributed beneath a structural cover of the Burntwood Group in the northeastern Kiseynew Domain. Metamorphic assemblages in the Wuskwatim Lake corridor indicate upper amphibolite and granulite facies conditions in Burntwood migmatite, as well as in the structurally underlying basement-cover sequence. A major implication of this work is that Thompson-type nickel mineralization may exist within the Ospwagan-like rocks present in the 60 km wide zone west of the TNB proper.

Thompson Nickel Belt

Two samples of the Pipe Formation in the TNB were processed for U-Pb sensitive high-resolution ion microprobe (SHRIMP) ages of detrital zircons in an attempt to

further constrain the age of deposition of the Ospwagan Group, which hosts the nickel deposits (Rayner, Percival [GSC] and Zwanzig [MGS]), GS-11). A pelite from the Thompson mine and semipelite from the Pipe II pit both yielded a population of exclusively Neoproterozoic grains with the primary age mode of ca. 2.7 Ga, similar to previous work on the entire Ospwagan Group sediment section. The simple distribution of detrital zircon ages can help to distinguish the nickel-hosting Ospwagan Group from other similar-looking rocks in northern Manitoba and thus delimit areas for nickel exploration.

Chris Couëslan (Ph.D. candidate, University of Calgary) conducted field investigations on the Hudsonian metamorphism of supracrustal rocks in the TNB (GS-12). Such studies are important because the character of Ospwagan Group metasedimentary rocks varies greatly with metamorphic grade, so documentation of their characteristics at different metamorphic grades will greatly increase the ability to recognize Ospwagan Group rocks throughout the TNB. Preliminary results suggest that grades may be higher along the eastern side and southern end of the belt and lower along the western side and northern end of the belt.

Far north

As part of the Manitoba Geological Survey's initiative to update the geological knowledge base of Manitoba's far north, field investigations in 2006 were focused on the Kasmere Lake and Putahow Lake areas (Böhm, Anderson and Matile; GS-13 and -14). Detailed bedrock mapping and sampling were undertaken for lithochemical, isotope geochemical and geochronological studies to improve the currently limited understanding of the nature and evolution of this portion of Manitoba's Precambrian shield, and to support ongoing uranium and gold exploration in the area. Bedrock exposures at Kasmere and Putahow lakes are divided into metasedimentary rocks of the Paleoproterozoic Wollaston Domain and younger, Paleoproterozoic granitic intrusions and pegmatite. Mineral exploration by private exploration companies and field mapping by MGS have discovered showings of uranium, gold and sulphides in the region. Landscape analysis in the Kasmere-Putahow lakes area underlines the importance of the distribution of subglacial meltwater-flow corridors when determining the bedrock source for mineral anomalies.

Mineral deposits studies

Bissett

In 2002, MGS initiated a program of bedrock mapping, structural analysis, lithochemistry, isotopic studies and geochronology in the Garner-Gem lakes area, 45 km southeast of Bissett. In the 2006 field season, Scott

Anderson conducted 1:20 000 scale bedrock mapping in the area in order to extend detailed mapping coverage into some poorly understood and complex areas east of the Manigotagan River and south of Gem Lake (GS-15). This work has resulted in a better understanding of the rock types, stratigraphy, structure and deformation history of the various supracrustal assemblages in the area. The geochemistry of rhyolite in one package suggests significant volcanic-hosted massive sulphide potential. This work also provides an improved context for a series of locally auriferous stockwork-breccia quartz-vein systems north of Gem Lake.

Bird River

In 2005, MGS initiated a government-industry-university partnership in the Bird River Belt of south-eastern Manitoba. Partners in the initiative include 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 will aid in supporting the exploration programs that are currently underway in the area.

Paul Gilbert continued his regional mapping project in the Bird River Belt with detailed mapping in the eastern part of the belt, focusing on stratigraphy and volcanic geochemistry (GS-17). This work has defined back-arc-basin-type and arc-type volcanic sequences, as well as turbidites and fluvial-alluvial deposits that post-date the arc-type rocks by approximately 30 m.y.

Field investigations in 2006 by University of Waterloo postdoctoral fellow Manuel Duguet on the north flank of the Bird River Belt focused on the structural relationships between the Maskwa Batholith and the different units of the Bird River Belt (GS-16). These investigations highlighted the importance of the Peterson Creek Shear Zone in the structural framework of this part of the belt. Stratigraphic subdivisions and structural interrelationships have been revised accordingly.

Paul Kremer (Waterloo University) continued M.Sc. work to examine the structural geology of the Bernic Lake Formation and provide constraints on the emplacement of contained rare element pegmatites (GS-18). Field components of the study included geological mapping (1:10 000 scale) of the Bernic Lake Formation around the Tanco mine, detailed geological mapping of exposed pegmatite occurrences within the Bernic Lake pegmatite group, examination of both production and exploration diamond-drill core from the Tanco mine, and underground mapping

of the Tanco pegmatite.

Caroline Mealin (University of Waterloo) continued M.Sc. work on the Bird River Sill, a mafic-ultramafic layered intrusion within the Bird River Belt (GS-19). The Bird River Sill is currently an exploration target for Ni-Cu-PGE deposits and hosts the past-producing Maskwa west and Dumbarton Cu-Ni deposits. Integrated detailed mapping, structural, geochemical and mineral deposit investigations have led to a new model for the emplacement of the ultramafic and mafic rocks that constitute the sill, with implications for sulphide and PGE mineralization. Several new sulphide-bearing localities have also been identified.

Snow Lake

A metallogenic and metamorphic study of selected gold-bearing deposits from Snow Lake and the southern flank of the Kiseynew Domain by McGill University Ph.D. candidate Simon Gagné (GS-4) is supported by MGS and GSC. During the 2006 field season, four gold-bearing mineral deposits, ranging from lower to upper amphibolite facies, were investigated (Chisel North, Nokomis Lake, Puffy Lake and Squall Lake). Examination of the sulphide-gold mineralization in these deposits will provide new constraints on the timing of mineralization and the possible effects of increasing pressure and temperature on the evolution of the sulphide-gold mineralization. This information will provide useful guidelines for explorationists to help in the selection of exploration targets in medium- to high-grade metamorphic terranes.

Phanerozoic investigations

Williston Basin TGI project

The 'Williston Basin Architecture and Hydrocarbon Potential' TGI project is a multidisciplinary geoscientific study aimed at characterizing and understanding basin architecture and hydrocarbon potential in the Williston Basin. This two-year study ended formally in March 2005, but work continues to complete and publish project products. Interprovincial subsurface stratigraphic correlations for the entire Phanerozoic section have been completed (Bezys, GS-23). Final map production for the project is to be completed by March 2007.

Cross-border correlations of the Bakken Formation, Three Forks Group stratigraphic interval coincided with the discovery of the Sinclair field, which is being explored for conventional oil. Co-operative maps and discussions between Manitoba and Saskatchewan have helped in the understanding of the dynamics of this new play.

The compilation of all oil and gas shows throughout the Phanerozoic section has also been a useful exploration tool for the industry, particularly in the Mesozoic, which was not compiled prior to the start of this project. The

recently constructed, detailed and accurate basin-wide model of the geohydrological dynamics of the Williston Basin system will be valuable for understanding oil-water migration pathways through the Phanerozoic section (particularly the Paleozoic).

Phanerozoic lineament study

A study to compile Phanerozoic structural information for the Western Canada Sedimentary Basin was begun by Jim Bamburak, in collaboration with the Alberta and Saskatchewan geological surveys (Bezys, GS-23). The joint prototype structural database has been designed to document structures that may have localized hydrocarbon and metal-bearing fluids in traps within the Phanerozoic stratigraphic package.

Surficial geology compilation of Manitoba

In 2006, thirty-seven 1:250 000 scale surficial geology maps, four 1:500 000 scale maps, and a prototype of the 1:1 000 000 scale map were produced by Gaywood Matile and Greg Keller, completing coverage of the entire province (Bezys, GS-23). The new maps will be in digital formats that can be queried (in addition to traditional hardcopy versions) and will be an important tool for mineral exploration and land-use planning.

Stratigraphic drilling

Two stratigraphic coreholes were drilled west of Lake Winnipegosis under the 2006 Corehole Drilling Program (Bamburak, GS-24). Devonian stratigraphic studies help not only to resolve stratigraphic problems, but may also provide a further understanding of metal migration-emplacment in an area where anomalous sequences exist. Historically, anomalous lead-zinc mineralization has been found in Devonian and Silurian formations that are situated within or updip of the Superior Boundary Zone. Consequently, there is potential for Mississippi Valley-type mineralization for more than 100 km along the trend of the Superior Boundary Zone in west-central Manitoba.

Aggregate

The Rural Municipality (R.M.) of Ste. Rose was mapped this year as part of an ongoing project to update aggregate information in the province (Groom, GS-22). The R.M. of Ste. Rose has been very fortunate to have an abundance of high-quality aggregate in the beach ridges in the area. Although many of the pits in the producing beach ridge are near depletion, it still contains large reserves of aggregate.

Other projects

Igneous carbonate-rich rocks from Wekusko Lake

The petrography, mineralogy and geochemistry of two macroscopically distinct drillcore samples of 'kimberlitic' rock from the southern Wekusko Lake area were examined in detail by researchers from the University of Manitoba and MGS (Chakhmouradian, Böhm and Greville, GS-5). The two studied samples are tentatively identified as magnesiocarbonatite, likely derived from a mantle source similar to those that produce kimberlite. In common with kimberlite, carbonatitic magma can potentially transport diamonds from the mantle. Further studies of the Wekusko Lake magnesiocarbonatite and its constituent minerals by isotope-analytical techniques will be required to constrain the source and evolutionary history of these rocks.

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 Scott St. George at the GSC (GS-20) uses a network of long-term discharge gauges to examine the frequency, severity and causes of drought in the basin during the last one hundred years. Understanding the dynamics of the Winnipeg River basin, including the causes of severe droughts and long-term trends, is critical to developing accurate estimates of future hydroelectric power production in Manitoba.

Revegetation of tailings at the Gunnar minesite

University of Manitoba researchers continued with a program investigating revegetation of mine tailings. A preliminary field experiment was designed to test the effects of tilling, fertilizing and amending Gunnar tailings with paper-mill sludge on plant establishment and growth (Renault, GS-21). Research oriented towards using readily available amendments, such as paper-mill sludge, to increase revegetation success on such sites would benefit the paper-mill industry and the mining industry, as well as the government and future land users.

Regional offices

The Flin Flon office continued to provide technical and regulatory assistance to the mining and mineral-exploration communities in northwestern Manitoba. These activities included recording new mineral claims and accepting applications and submissions required under *The Mines and Minerals Act*, answering claim-status and other *Act*-related inquiries, and maintaining a collection of current claim and land-status maps for the

Province of Manitoba (Heine, GS-6). The office staff includes the Regional Geologist (Tom Heine), Resident Geologist (David Prouse), Deputy Mining Recorder (Tana White) and Claims Inspector (Dale Wride).

Core storage facilities

The Mineral Resources Division considers the archiving of exploration drillcore to be a valuable data source for use by mineral-exploration companies and researchers. Drillcore storage facilities are located in Winnipeg (Midland and Brady Road), The Pas, Flin Flon, Thompson and Lynn Lake (Prouse, GS-25). Clients can access drillcore for viewing and study at these locations. Six of the core libraries have lighted, heated inspection rooms with benches, and most have core splitters. It is estimated that the Manitoba Geological Survey's Precambrian drillcore libraries currently contain more than 260 000 m of core.

Compilation and partnerships

The Manitoba Geological Survey is engaged in 34 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 2006–2007, and represent significant leverage of the MGS geoscience budget. The projects facilitate the training of future geoscience professionals, including in 2006 two postdoctoral fellows, four Ph.D. candidates, five M.Sc. candidates and three Honours B.Sc. students. Primary focuses for partnerships in 2006 were the Flin Flon TGI project and the Bird River suite of projects.

Geoscience Information Services

In 2006, the Geoscience Information Services section devoted considerable time to a number of major projects and many smaller projects in support of the Geological Survey's research activities. Major projects included the following:

- Williston Basin Hydrocarbon Potential project (TGI-2): More than 200 isopach and structure contour maps have been produced using a standardized database combining Manitoba and Saskatchewan data.
- Manitoba Geochronology Database: This database was rereleased in November 2005 after verification of all data currently entered and standardization of geological and bibliographic information.
- Bedrock Geology Compilation Map program: Recompilation and updating of existing maps to produce a seamless 1:250 000 scale digital geological base for Manitoba has been completed for approximately half the province.
- Compilation of the Thompson Nickel Belt based on

the work of J. Macek and H. Zwanzig: More than a million hectares of the TNB have been compiled into a seamless geodatabase that includes an upgraded topographic base incorporating detailed infrastructure, geology and several thousand structural measurements. These data are being released as an Open File digital dataset, to be followed in 2007 by individual final maps.

Mineral Deposits Database

The Mineral Deposits Database currently used to support the Map Gallery presentation is being redesigned as an Oracle database (Heine, GS-26). A considerable mineral deposit-occurrence archive is currently compiled in the Mineral Inventory Cards and Mineral Deposit Report series (both via the Internet; the latter accessible through the Map Gallery). The newly designed database will centralize all mineral deposit data currently available and provide users with a search engine to customize queries. The database design is complete and porting of data from the old system to the new database is underway. Version 1 of the database should be ready for release (on CD-ROM) by November 2007.

Client services and outreach

In 2005–2006, MGS published seven geoscientific reports, including the annual *Report of Activities*, and 38 maps. In response to client needs, the majority of the publications were released in hard copy 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 Schools Program, National Engineering and Geoscience Week, and Provincial Mining Week. The latter offered free, hands-on activities developed to complement the earth sciences curriculum and help increase public awareness of Manitoba's mineral resources and mining industry. The event drew more than 4000 visitors from the general public and the school tours program.

A number of MGS staff, including Vanessa James, Ruth Bezys, Elaine Stevenson and Peter Leskiw, contributed to the development and delivery of the Prospector Training Program module, entitled 'Business of Prospecting'. Eleven students who had already graduated from the Wilderness Safety and Prospector Training modules attended the Business of Prospecting program held in November of 2005. Course topics included raising venture capital; listing, describing and selling a property; marketing; joint ventures; and information sources and research.

Elaine Stevenson, the MGS outreach programs co-ordinator, also organized the 2nd annual Aboriginal

Mining Workshop, which was held as part of the November 2005 Manitoba Mining and Minerals Convention and drew 48 participants. The workshop focused on how communities can benefit from mineral exploration activity in their regions.

Survey staff delivered mining and geology presentations to Aboriginal communities and schools in Cross Lake, Oxford House and Hollow Water, as well as at the Assembly of Manitoba Chiefs Youth Gathering and St. John's Ravenscourt. In addition, staff attended Aboriginal conferences, such as Vision Quest, the Northern Association of Community Councils and the Canadian Aboriginal Minerals Association.

An article on mineral exploration in northern Manitoba was published in the Community Contact

newsletter distributed by Manitoba Aboriginal and Northern Affairs. The article describes the mining cycle, potential job and business opportunities, the location of exploration projects and how communities and individuals can learn more and participate.

Acknowledgments

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