Manitoba
Industry, Trade
and Mines
Geological Survey

REPORT OF ACTIVITIES
2000

2000

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REPORT OF ACTIVITIES 2000

A message from the Minister:

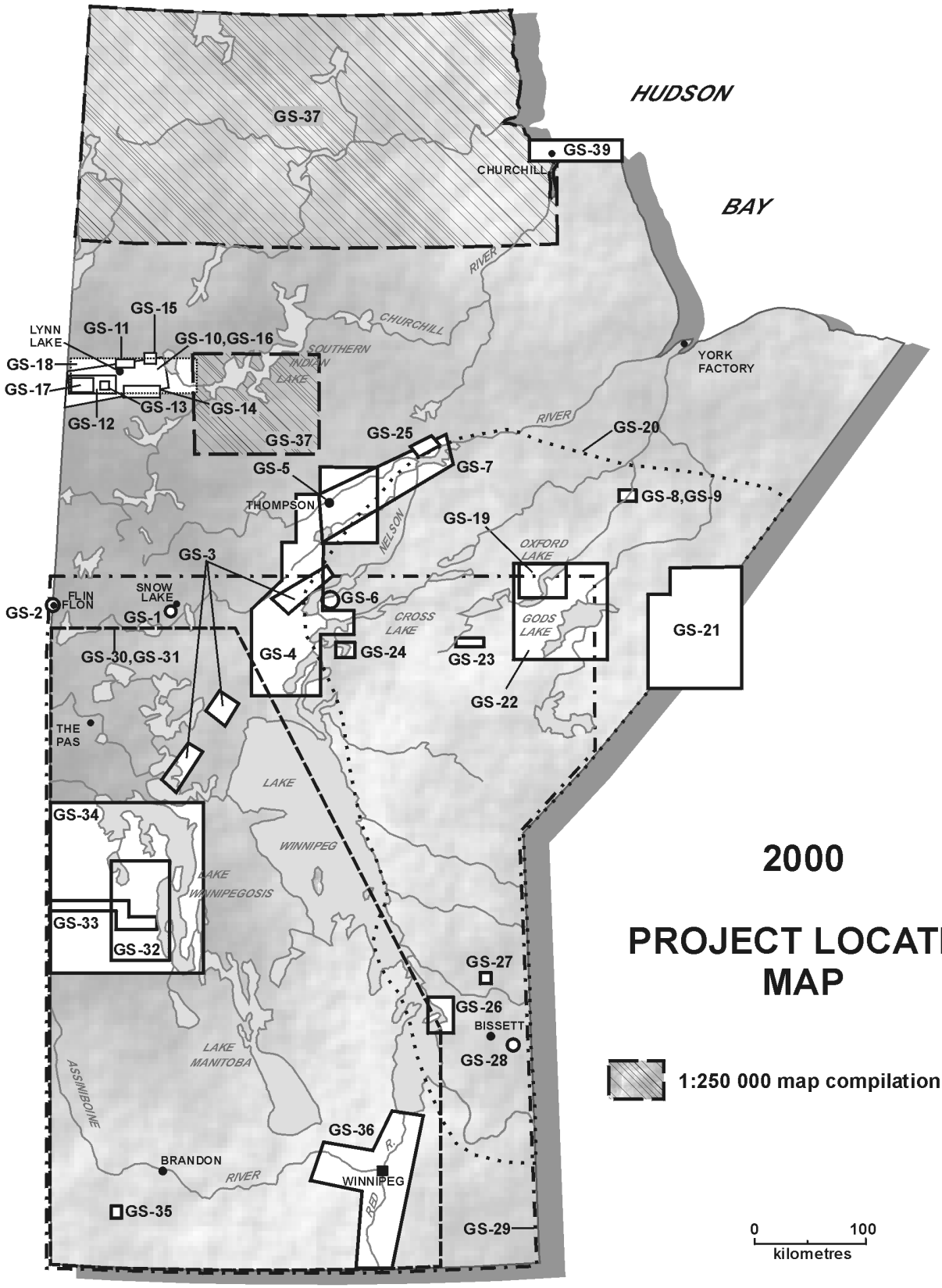
Manitoba is one of the best places in the world to invest in exploration and mining. Our province enjoys many strategic advantages in this sector, not the least of which is its mineral resource endowment. One of our greatest assets is the skill and dedication that staff of the Manitoba Geological Survey bring to unraveling the secrets of Manitoba's mineral potential.

The **Report of Activities** is a comprehensive summary of the geoscience investigations carried out by departmental geological staff during the 2000 field season. It also includes contributions reporting on collaborative projects with a number of Canadian universities, the mining and mineral industry, and various geoscience organizations across Canada. It is our intent to provide the mining and exploration industry with the most current geoscience information possible, to help focus exploration strategies for the coming year.

The geoscience community will note that this year the Geological Services Branch has been renamed the *Manitoba Geological Survey*. This new name more clearly reflects the role of the Branch and is consistent with usage in other provincial geological survey organizations across Canada. The Survey recognizes the importance of the mining industry to the Manitoba economy and is committed, with the rest of the department, to supporting initiatives that ensure the long-term viability of the mining industry and mining communities.

The release of this report at the 2000 Manitoba Mining and Minerals Convention creates an ideal forum to stimulate discussion and produce beneficial consultations between Manitoba Industry, Trade and Mines staff and stakeholders in the Manitoba mining community. The mining and minerals industry has an important role to play in the Manitoba Government's vision for a prosperous and dynamic economy that generates sustainable employment growth for all Manitobans. I hope this report provides you with the solid geoscience base you need to plan your next exploration venture in Manitoba.

Honourable MaryAnn Mihychuk
Minister of Industry, Trade and Mines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by E.C. Syme, Acting Director, Manitoba Geological Survey

Syme, E.C. 2000: Introductory summary; *in* Report of Activities, 2000, Manitoba Industry, Trade and Mines, Manitoba Geological Survey, p. 1-8.

This millennial year marks the 71st year (since 1929) that a Manitoba government agency has conducted geological investigations within its jurisdiction. Annual publications devoted solely to geological investigations in Manitoba began in 1968, making the *Report of Activities 2000* the 33rd annual publication of its kind. *Report of Activities* has grown over time to become a rich source of geoscience information. The steady expansion in scientific content reflects the commitment of Manitoba Geological Survey staff to excellence in their submissions. The increasing involvement of university, federal government and industry partners in our geological investigations has broadened the scope of the activities reported in the pages that follow.

The full text and graphic content of individual reports in the *Report of Activities 2000* can be downloaded, free of charge, from the departmental web site, by pointing your browser to http://www.gov.mb.ca/em/geoscience/geo-index.html and following the links.

GEOSCIENCE PROGRAM

The primary mandate of the Manitoba Geological Survey (MGS) is to provide public sector, accessible, reliable geoscience information — material that is required by industry to attract investment in the increasingly competitive global mineral and petroleum exploration markets. By developing an understanding of Manitoba's geology and geological processes, the MGS also contributes to decisions regarding land-use management. To help meet these objectives, funding for the Manitoba Geological Survey was increased in 2000 to $4.4 million.

Major field-based activities conducted by the MGS include bedrock mapping at a number of scales, as well as more specialized, thematic projects. Compilation maps and regional syntheses (1:50 000 scale or smaller) provide up-to-date regional-scale information for both the major mining districts of Manitoba and the frontier areas of the province. They also provide geological background and mineral-resource assessments in support of land-use planning and sustainable development. Thematic studies (1:20 000 scale or larger) address specific geological and land-use problems, support mineral-deposit studies and compilation-series mapping, and identify new methods of assessing and defining mineral potential for a variety of traditional and nontraditional mineral-deposit types. Specialized geochemical and geophysical projects provide regional data to assist industry in the identification of prospective areas. Maintenance of a mineral-deposit inventory provides a systematic catalogue of metallic-mineral, industrial-mineral and aggregate deposits.

The 2000–2001 geoscience program reflects a balance between providing support to traditional mining camps, stimulating new exploration and development opportunities in frontier areas, and supporting land-use and development priorities in southern Manitoba. The program is reviewed annually by the Mineral Exploration Liaison Committee (MELC), composed of members of the Mining Association of Manitoba, the Manitoba Prospectors and Developers Association, and the Manitoba–Saskatchewan Prospectors and Developers Association, as well as representatives from the University of Manitoba and the Geological Survey of Canada (GSC).

The MGS geoscience program is designed with a regional emphasis, focusing on those areas most in need of new or updated geological information. Programs are generally designed on a cycle that allows the geographic focus of activities to shift from area to area within the province. In 2000–2001, approximately 41% of operating resources are directed toward studies in the northern Superior Province, a reflection of the Department's five-year initiative to stimulate exploration in this underexplored part of the province. Approximately 40% are directed toward projects within traditional mining camps (Flin Flon Belt, Lynn Lake Belt, Thompson Nickel Belt and southeastern Manitoba). The remaining 19% support Quaternary, aggregate, industrial minerals and land-use planning in the south-central part of the province, as well as GIS support for all projects.

Partnership Programs

Geoscience programming in Manitoba is delivered through a combination of provincially funded and collaborative projects. The partnered initiatives include contributions from the federal government, the mineral exploration industry and several Canadian universities (Table 1). These partnerships are anticipated to add an additional $1.0 million to operating field expenditures in 2000/01, effectively matching the amount of operating funds spent on geoscience by the province.

Targeted Geoscience Initiative

A new federal government program aimed at providing additional funding for geoscience in Canada was introduced in the 2000 federal budget. The Targeted Geoscience Initiative (TGI) brings $5 million per year in new federal spending, for three years, to projects across the country. The goal of the TGI is to turn resource potential into new social and economic benefits by increasing the level and effectiveness of private-sector mineral exploration. By improving the quality and quantity of available geoscience information and promoting its rapid dissemination on the Internet, the TGI will help stimulate new investment in the mining sector.

Targeted Geoscience Initiative projects are agreed upon and delivered collaboratively by the GSC and provincial/territorial surveys, based on priorities developed in concert with local technical advisory committees (MELC in Manitoba). Manitoba-based TGI projects approved and in progress to date include:

- **Regional hydrothermal systems as an exploration guide, FlinFlon mining camp, Manitoba and Saskatchewan:** With combined federal and provincial funding of approximately $800 000 over three years, this project will include studies of 1) the mineralogical and stable-isotope characteristics of alteration below and above the Flin Flon–Callinan–777 stratigraphic interval, 2) the nature of regional deformation patterns affecting the Flin Flon VMS horizon, 3) the reconstruction of the nature and distribution of volcaniclastic rocks associated with the Flin Flon VMS horizon, 4) the nature and distribution of hydrothermal alteration within the Bear Lake and Bakers Narrows blocks, 5) regional oxygen-isotope alteration, and 6) the geochemistry of the Flin Flon massive-sulphide deposits. An orientation survey was conducted during a short field season in 2000, but the main work associated with the Flin Flon TGI will commence in 2001.
- **Southeastern Manitoba–Red Lake (Ontario) digital compilation:** With combined federal and provincial funding of approximately $403 000 over three years, this project will provide the necessary resources to collect a variety of geological, geochemical and geophysical data sets, in digital form, for an area in northwestern Ontario and southeastern Manitoba. The aim is to produce a CD-ROM containing all available, integrated geospatial data for the region, to aid all types of mineral exploration in the region from the Red Lake Belt in Ontario to the Rice Lake and Bird River belts in Manitoba. Work on the Southeastern Manitoba–Red Lake TGI will begin in the fall of 2000.

The MGS and the GSC will work together to propose additional projects in priority areas of the province, for years two and three of the Targeted Geoscience Initiative. Given that TGI is a federal program,

Table 1: Collaborative Geoscience Programs in Manitoba, 2000-2001.

Region	Project and partners
Thompson	Thompson Nickel Belt CAMIRO (INCO Ltd., Falconbridge Ltd., HBED, Billiton Metals Canada Inc., Western Mining International Ltd., GSC, U of Manitoba, Laurentian U, U of Alberta, U of Québec at Montréal, U of Saskatchewan, NSERC)
Thompson	Thompson Nickel Belt compilation (INCO Ltd., Falconbridge Ltd., HBED)
Superior BZ	Fox River Belt geology and metallogeny (Falconbridge Ltd.)
Superior BZ, Northern Superior	Western Superior LITHOPROBE (U of Waterloo, U of Alberta, NSERC)
Northern Superior	Western Superior NATMAP (OGS, GSC, universities, LITHOPROBE, NSERC)
Lynn Lake	Lynn Lake gold studies (U of New Brunswick, Laurentian U, U of Manitoba, NSERC)
Snow Lake	Subvolcanic intrusions CAMIRO (now completed; GSC, universities)
Flin Flon Belt	Shield Margin NATMAP (now completed; GSC, SGS, universities, LITHOPROBE)
Flin Flon Belt	Flin Flon Belt geochronology (HBED)
Flin Flon Belt	Flin Flon TGI project (GSC, SGS, industry)
Interlake	Hydrogeology (GSC, WRB, U of Manitoba)
Southeastern Manitoba	Southeastern Manitoba-Red Lake TGI project (GSC, OGS)
Southern Manitoba	Greater Winnipeg NATMAP (GSC, universities)
Southern Manitoba	Paleofloods of the Red River (GSC, IJC, RRFPP)

Abbreviations: CAMIRO, Canadian Mining Industry Research Organization; GSC, Geological Survey of Canada; HBED, Hudson Bay Exploration and Development Ltd.; IJC, International Joint Commission; LITHOPROBE, Canada's National Geoscience Program; NATMAP, National Geoscience Mapping Program; NSERC, Natural Sciences and Engineering Research Council; OGS, Ontario Geological Survey; RRFPP, Red River Flood Protection Program; SGS, Saskatchewan Geological Survey; Superior BZ, Superior Boundary Zone; TGI, Targeted Geoscience Initiative; U, University; WRB, Water Resources Branch.

final approval of projects rests with the GSC. However, independent of the success of future TGI proposals, the MGS will continue to address critical geoscience needs in the province.

Brief summaries of the results obtained during the 2000 field season are provided below, arranged according to the geographic area in which they were conducted.

FLIN FLON–SNOW LAKE

The NATMAP Shield Margin Project, completed in 1998 with the publication of a set of 1:100 000 scale compilation maps and accompanying notes, was the culmination of twenty years of MGS mapping and mineral-deposit investigations in the Flin Flon Belt. The scientific results of the Shield Margin Project have now been published in two volumes of the Canadian Journal of Earth Sciences (January and November 1999). A CD-ROM containing the compilation maps and a variety of other digital data sets (potential field images, geochemistry, geochronology, selected 1:50 000 and 1:20 000 scale maps, field data) was released in May of this year.

With the completion of the Shield Margin Project, the intensity of MGS field investigations in the Flin Flon Belt has decreased. However, the important lessons learned during the Shield Margin Project, in terms of greenstone belt complexity and project methodology, are now being applied in the Western Superior NATMAP project and in the Lynn Lake Belt. Most current projects in the Flin Flon Belt have a specific mineral-deposit orientation (e.g. gold deposits in the Snow Lake area, documentation of VMS deposits from mine plans and new sampling). In the effort to complete the Shield Margin Project, work on a large number of 1:5 000 to 1:20 000 scale maps was put on hold, and we now intend to begin publishing final maps for completed projects. These detailed maps will form the basis of a new 1:50 000 scale compilation series for the belt. As described above, the Targeted Geoscience Initiative projects will bring joint MGS–GSC–Saskatchewan Geological Survey resources to bear on specific base-metal–related topics in the western Flin Flon Belt.

At Snow Lake, an alteration study was undertaken as part of a B.Sc. thesis at the University of Manitoba. This study comprises detailed mapping (1:1 000 scale) and sampling of an outcrop of silicified basalt, and comprehensive mineralogical and geochemical studies. It is designed to fully characterize the nature of the synvolcanic hydrothermal alteration and to provide a comprehensive understanding of the silicification event.

LYNN LAKE–LEAF RAPIDS

A variety of new initiatives began in 2000 in the Lynn Lake region, in response to the closure of the Keystone mine's Farley deposit, formerly the only active mining operation in Lynn Lake. These initiatives include new regional and detailed structural mapping in the Johnson Shear Zone (JSZ) and Agassiz Metallotect, selected multimedia geochemical surveys, and a GIS compilation project that will house not only the newly acquired information but also a wide variety of existing data not readily available at present. An M.Sc. study, currently underway at the University of Manitoba, utilizes existing and new digital data sets in the Lynn Lake area to develop a predictive tool for gold exploration. These initiatives augment MGS office-based compilation initiatives, including production of new 1:50 000 scale colour maps for the belt and updated geochemical data pertaining to the volcanic stratigraphy of the belt.

Gold Metallogeny in the Lynn Lake Belt

Many MGS investigations in the Lynn Lake greenstone belt are intended to improve understanding of processes involved in the formation of gold mineralization in the region. The objective is to provide the exploration community with metallogenic models for the formation of Lynn Lake–type gold deposits. The 2000 field season was the second year of a multiyear, multifaceted gold metallogeny project that represents a significant expansion of MGS efforts in the Lynn Lake Belt. The initial fieldwork, started during the 1999 field season, focused on the deformation history of the Johnson Shear Zone and the relationship to gold mineralization hosted by the shear zone. Fieldwork completed during the 2000 season saw a continuation of the 1999 program and the addition of thesis projects investigating past-producing gold deposits associated with the JSZ and Agassiz Metallotect.

The Johnson Shear Zone is a major east-trending, pre–peak metamorphism shear zone located in the southern Lynn Lake Belt.

Evidence is accumulating for a long history of movement along the shear zone, with the majority of observed shear fabrics representing a major period of reactivation of an older structure. Mapping in 2000 extended the JSZ to the Dunphy Lakes area, west of Gemmell Lake, for a total strike length that is now known to exceed 100 km. Gold mineralization west of Gemmell Lake, associated with sheared and altered felsic volcanic rocks, is characterized by the presence of very fine grained acicular arsenopyrite and local finely disseminated pyrite, zones of syn-shear quartz veins, silicification and weak sericitization. The gold mineralization west of Gemmell Lake, hosted by sheared felsic volcanic rocks, represents a different and previously unrecognized style of mineralization within the JSZ and has excellent gold exploration potential. A second style of mineralization, informally termed 'BT-style' after the Burnt Timber gold deposit, is associated with finely disseminated pyrite in highly silicified, carbonatized, sheared mafic volcanic rocks. The silicification is accompanied by moderate biotitization, reflecting syn-shear potassic metasomatism.

The Agassiz Metallotect is an economically important, broadly stratiform zone of regional extent that hosts significant gold deposits within the northern Lynn Lake Belt. Preliminary mapping and detailed structural analysis in the western portion of the metallotect has identified five generations of structural fabrics formed by discrete deformational events. Stratabound gold mineralization within the metallotect occurs in both metavolcanic and metasedimentary rocks. Associated hydrothermal alteration includes calcic amphibolitization, biotitization, muscovitization, silicification and carbonatization, as well as chloritization and serpentinization of the host high-Mg-Ni-Cr basalt (picrite) and fine-grained sedimentary rocks. Gold mineralization seems to be principally associated with the second-generation carbonate-quartz-sulphide veins crosscutting the sulphidic metasiltstone.

Preliminary structural and geochemical investigations of the Farley Lake gold deposit have determined that the gold mineralization is associated with the emplacement of postdeformational, postplutonism quartz-carbonate-sulphide veins into banded oxide- and silicate-facies iron-formation, resulting in sulphidization of the iron-formation. The high-grade quartz-carbonate-sulphide veins were emplaced along pre-existing, shallowly southwest-dipping joints and subvertical, second-generation faults and shear zones. The thick sequence of iron-formation and interbedded argillaceous sedimentary rocks that hosts the mineralization has experienced significant first- and second-generation fold thickening.

Mineralization-Potential Mapping, Lynn Lake

The construction of a regional database of geological and geophysical data for the Lynn Lake Belt was begun in 1999 as an M.Sc. study at the University of Manitoba. The objective of the project is to produce mineralization-potential maps using a GIS platform and data-fusion technique. Data sets compiled include regional geology, lithogeochemistry, lake sediment and till geochemistry, airborne geophysics, and synthetic aperture radar (SAR) data. A preliminary set of mineralization-potential maps for shear-hosted and VMS-type deposits, produced using theoretical principles, show good correlation with known mineral occurrences throughout the southern portion of the Lynn Lake Belt.

Volcanic Stratigraphy and Geochemistry, Kisseynew North Flank

With the publication of new trace-element data from the Lynn Lake Belt in 1999, additional follow-up work was conducted within the boundary zone between the Lynn Lake Belt proper and the Kisseynew Domain. This work helps to define the extension of Lynn Lake Belt tectonostratigraphic assemblages into the more highly deformed and recrystallized domain to the south. Highly recrystallized, mafic to ultramafic volcanic rocks, previously mapped as undifferentiated amphibolite, can be distinguished geochemically in the same manner as in the better preserved rocks of the Lynn Lake Belt. Volcanic units in the Kisseynew margin have geochemical and metallogenic affinities to volcanic arcs, marginal-basin floor (N-MORB and contaminated MORB) and ocean-island basalt. Despite structural attenuation and alteration involving alkali elements, the content of the least mobile elements in assemblages is remarkably uniform for tens of kilometres along strike and provides a valuable tool for mapping. Major structural breaks separate the arc and marginal-basin assemblages, even where units were attenuated to a thickness of only a few metres. Shear zones that reactivate or cut these breaks may host precious-metal deposits.

New Geochronological Results from the Lynn Lake Belt

Geochronological studies are helping to establish the geological evolution of the Lynn Lake Belt. New U-Pb ages suggest that the bulk of plutonic activity, both mafic and felsic, occurred during the period 1870–1876 Ma. The nickeliferous 'EL' and barren Fraser Lake gabbroic stocks, both of which intrude the Wasekwan Group arc-related metavolcanic rocks in the Lynn Lake area, have yielded U-Pb zircon ages of 1871.3 ± 2.4 Ma and 1870 ± 6.2 Ma, respectively. The Eden Lake granite, intruding gneissic tonalite at the southeast end of the Lynn Lake Belt, yielded an age of 1870 ± 10 Ma that is comparable to the age of the gabbros and to the published ages of the Hughes Lake and Norrie Lake tonalite plutons. The age of a tonalite pluton north of the Fox Lake mine, at the southwest end of the Lynn Lake Belt, is significantly younger at 1831 ± 3.7 Ma. The 1831–1871 Ma period of intrusive activity indicated by this new work is similar to the span of 'successor arc' magmatism determined elsewhere in the Trans-Hudson Orogen.

THOMPSON NICKEL BELT–FOX RIVER BELT

Thompson Nickel Belt

The MGS has turned a significant part of its attention to the Thompson Nickel Belt (TNB), an area that, despite its economic importance to the province, has historically seen relatively little provincial survey work due to limited bedrock exposure and a large amount of hitherto confidential company information. Recognition by all stakeholders that the public geological database for this world-class mineral belt required major updating resulted in two initiatives, both supported by industry and both entering their final stages in 2000–2001:

1) Compilation of the geology of the exposed TNB and its sub-Phanerozoic extension, begun in 1995, has been made possible by the generous co-operation of INCO Ltd., Falconbridge Ltd., and Hudson Bay Mining and Smelting Co. Ltd., allowing MGS access to virtually all private-sector information in the TNB. Preliminary versions of the maps are planned for publication in the spring of 2001.
2) The Thompson Nickel Belt CAMIRO project brings researchers from universities and government together to develop new exploration tools for the TNB in a four-year (1997–2001) study, in part funded by industry (*see* below).

Thompson Nickel Belt bedrock geology compilation

The geological compilation of the TNB progressed this year with the completion of NTS sheets 63F/08, 63F/09, 63G/14 and 63J/03. During the summer, diamond-drill cores from 317 holes from a broad area around Wabowden were re-examined. Thirty per cent of these drillholes contain Ospwagan Group metasedimentary rocks, host rocks to the Thompson-type nickel deposits. This new work is notable because no Ospwagan Group rocks were shown on the 1972 compilation map of this area. Although only one-third of the available core was examined in the summer of 2000, major lithological trends will be compiled onto maps from the newly obtained data. Re-logging of additional drillholes will be undertaken in the summer of 2001 to further refine the compilation map.

In concert with the TNB compilation, petrographic and geochemical studies were conducted to provide detailed mineralogical data for the Ospwagan Group, Kisseynew Domain rock units and reworked Archean gneiss in and adjacent to the Thompson Nickel Belt.

Thompson Nickel Belt CAMIRO Project

The Thompson Nickel Belt CAMIRO Project has a combined industry–NSERC budget of approximately $800 000, and is administered by the Canadian Mining Industry Research Organization (CAMIRO). The MGS co-ordinated and led the project until August of 2000, when personnel changes required that these responsibilities be split between coleaders at the University of Manitoba and Laurentian University. The project currently has five industry sponsors (INCO Ltd., Falconbridge Ltd., Hudson Bay Exploration and Development Ltd., Billiton Metals Canada Inc. and Western Mining International Ltd.) and researchers from the GSC, the University of Manitoba, Laurentian University, the University of Alberta, the University of Québec at Montréal, and the University of Saskatchewan.

Regional mapping in the TNB

At Mystery Lake, a regional syncline has a core of Ospwagan Group metasedimentary and metavolcanic rocks that were intruded by large ultramafic bodies. The Archean basement gneiss on the limbs of the syncline contains high-strain zones that feature kinematic indicators interpreted to be the result of northwest shortening with dominantly sinistral, east-side-up displacement. The Mystery Lake data suggest that northwest compression and vertical extension were dominant, and that megaboudinage may have caused a local reversal in the horizontal shear component. The results do not support a model involving only dextral transpression, but are instead consistent with the structural style of undisrupted, long, sinuous folds that has been identified during preparation of a compilation map of the Thompson Nickel Belt.

The metamorphic transition between the Archean Pikwitonei Granulite Domain and the Paleoproterozoic, amphibolite-grade Thompson Nickel Belt was examined on western Sipiwesk Lake. Fieldwork focused on collecting samples from layers of leucocratic, mesocratic and melanocratic rocks that could be reliably traced across this well defined metamorphic boundary. In addition, a series of samples was collected from a well exposed, layered, mafic-ultramafic complex in the Pikwitonei Domain to study metamorphic reaction textures at granulite grade. Results of these studies will be reported in a B.Sc. thesis currently in progress.

Fox River Belt

Falconbridge Ltd. launched a major Ni-Cu-PGE exploration program in the Fox River Belt (FRB) in 1999. This new exploration work provides the MGS with an opportunity to advance the geological database for the belt, which is the largest continuous segment of the Superior Boundary Zone in Manitoba. The MGS completed a reconnaissance field study of the FRB in 1999, and results obtained from this program provided strong impetus for a multiyear geological investigation of the metallogeny, petrogenesis and tectonic evolution of the belt.

The 2000 field program included reconnaissance geological studies in the western part of the FRB. The Lower Sedimentary formation and the adjacent Archean orthogneiss of the Superior Province host one or more suites of previously unrecognized mafic intrusions. Granitic rocks locally intrude the Lower Sedimentary formation in the southwestern part of the Fox River Belt, and may relate to previously unknown Proterozoic felsic plutonism within the Archean–Proterozoic boundary. In the Fox River Belt, most of the sedimentary rocks are undeformed and consist of repeated cycles, tens of metres thick, of early clastic and later chemical sedimentation. Limited sedimentological studies of the Middle Sedimentary formation and upper parts of the Lower Sedimentary formation suggest a strong similarity to the distal marine sedimentary rocks in the prospective parts of the Ospwagan Group in the Thompson Nickel Belt. The FRB is bordered on the north by paragneiss, with turbiditic greywacke protoliths, that has been folded and metamorphosed at amphibolite facies. This paragneiss was sampled in 2000 to determine its Nd-Sm model age.

The Great Falls area provides the best known exposures of the Fox River sill within the Fox River Belt. Mapping completed in 2000 focused on the Marginal Zone outcrops and enabled completion of a 1:1000 scale geological map of the northern half of the Great Falls outcrop area. Mapping has shown that the lower part of the Fox River sill in this area is largely undeformed and has a chilled contact with older pyritic mudstone and siltstone of the Middle Sedimentary formation. Surface prospecting has delineated disseminated Fe-Cu-Ni sulphide mineralization within the Marginal zone at three different stratigraphic levels. The KO zone is a stratabound zone of sulphide mineralization, enriched in Cu, Ni and platinum-group elements (PGE), that developed immediately above the irregular contact between the host ultramafic rocks of the second cyclic unit and the upper, leucogabbroic part of the first cyclic unit. Recent analytical results confirm the PGE-rich nature of the KO zone, which has a maximum grade of 5.4 g/t combined Pd+Pt+Au, 2.3% Cu and 1.1% Ni.

Ongoing research of the Marginal zone geology and mineralization is being carried out as a Ph.D. thesis at the University of Manitoba. This research will provide new geological, mineralogical and geochemical observations that will allow the development of rigorous genetic models for the emplacement and mineralization of the KO zone. On a regional scale, ongoing detailed investigations of the Fox River sill will continue to provide constraints on its emplacement and crystallization. One hypothesis currently being tested, which is consistent with many recent field and geochemical observations, is that the Fox River sill was emplaced on a subvertical, syn-rift, axial fault system, and is therefore a major dyke.

NORTHERN SUPERIOR PROVINCE

Manitoba's five-year Northern Superior initiative is now in its final year of data collection. The objectives of this initiative are broadly to: 1) identify regional exploration targets through new geochemical surveys and compilations of geophysical data derived from assessment files; and 2) provide the geological framework for mineral exploration through regional mapping and thematic studies. This program is linked to the larger Western Superior NATMAP project that is focused on defining the crustal evolution and tectonic assembly of the Superior Province west of Lake Nipissing.

Multimedia Geochemical Survey, Knee Lake

Operation Superior, begun in 1996, involves helicopter-supported multimedia geochemical surveys targeting greenstone belts in the northern Superior Province. During the 2000 field season, approximately 2000 rock, till, b-horizon, humus and vegetation samples were collected for multi-element geochemical analysis from 350 sites within the northern portion of the Knee Lake greenstone belt. In addition, 334 bulk samples of till and beach sand were collected for identification and analysis of kimberlite indicator minerals. The geochemical and mineralogical analysis of these samples will continue to build a multi-element–multimedia geochemical database to assist mineral-resource assessment in the northern Superior Province of Manitoba. Future directions include a joint data-integration project conducted by the MGS and the GSC, to produce a belt-by-belt multi-element–multimedia product that will highlight and prioritize areas of mineral potential.

Regional Mapping in the Northern Superior Province

Regional (1:20 000 to 1:50 000 scale) bedrock geological mapping is being conducted in selected greenstone belts in the northern Superior Province, including current work in the Knee Lake–Gods Lake, Stull–Kistigan–Edmund lakes, and Max Lake–Aswapiswanan Lake areas. Lithological, geochemical, structural and geochronological data collected during these projects, in partnership with GSC and University collaborators, will be critical for interpreting the setting of known

mineral deposits and to better assess the mineral-development potential of the region.

The Western Superior NATMAP project, now in its fourth year of operation, aims to provide a modern geoscience synthesis of northwestern Ontario and eastern Manitoba, using the combined resources of the federal, Ontario and Manitoba geological surveys. Key areas have been selected to address questions regarding relationships between Mesoarchean and Neoarchean sequences of the western Superior Province, through new mapping, geochemistry, geochronology and GIS-based compilation. Field and isotopic data on plutonic and supracrustal rocks from the northwestern Superior Province reveal a complex history involving three fault-bounded crustal terranes. These terranes record the collision between reworked 3.6 Ga crust in the north and a less than 3 Ga protocraton at 2.72–2.71 Ga.

A regional mapping program, begun in the Knee Lake area in 1997, continued to the northeast in the Gods Lake area in 2000. Geochronological studies yielded several important ages, indicating that the Oxford Lake Group volcanic subgroup has a 2720 Ma depositional age and that the Oxford Lake Group sedimentary subgroup has a broad range of detrital zircon ages ranging from 2711 to 3647 Ma. Geochronological data from the Knee Lake area date Hayes River Group volcanism at 2830 Ma. Folding of the Hayes River Group predates deposition of the coarsening-upward Opischikona clastic sedimentary package and iron-formation, the former containing 2937 to 2822 Ma detrital zircons. The Oxford Lake volcanic subgroup was emplaced at 2722 Ma in southern Knee Lake and was followed by deposition of fluvial sandstone with detrital zircons ranging from 2798 to 2707 Ma.

Mapping in the Ralph Anderson Lake greenstone belt, southeast of Thompson, was conducted as a follow-up to mapping carried out in the adjacent Max Lake area in 1999. The Ralph Anderson Lake belt extends from Logan Lake in the west to Aswapiswanan Lake in the east, a distance of about 50 km. The greenstone belt is essentially monoclinal, and consists mainly of arc-type mafic volcanic rocks, with subordinate felsic volcanic and sedimentary units. The widespread synvolcanic hydrothermal alteration prominent in the Max Lake area was also noted in this new map area. Stratabound sediment-related mineralization occurs at various stratigraphic levels within the mapped volcanic suites. Sulphide mineralization is also common in magnetiferous iron-formation units, which offer potential base-metal or precious-metal exploration targets. Sporadic pyritic zones that may represent prospects for economic mineralization also occur at the junction between the volcanic terrane and gabbro at the south margin of the greenstone belt. A gabbro-pyroxenite intrusion that extends through the central part of the Ralph Anderson Lake belt is currently being tested for possible PGE mineralization.

An M.Sc. study at the University of Waterloo focuses on the kinematic history of east-southeast-trending shear zones in the Pipestone Lake area of the Cross Lake greenstone belt. The south Pipestone Lake and north Pipestone Lake shear zones both underwent two main generations of shear deformation, the first associated with mylonite development under amphibolite-grade conditions and the second associated with shear under greenschist-grade conditions. Observations made during the structural study suggest that megacrystic anorthosite of the Pipestone Lake Anorthosite Complex intruded the basalt-dominated Pipestone Lake Group during or after an initial deformation event, suggesting that the proposed theory of comagmatism should be reconsidered.

Northwest Superior Boundary

An MGS- and NSERC-supported, integrated mapping, geochemistry and isotopic study of the Western Superior craton margin northeast of Thompson has been partnered with researchers from the University of Alberta. Over the past three years, this work has indicated that a re-interpretation of the location and nature of the boundary zone between the Archean Superior Province and the Paleoproterozoic Trans-Hudson Orogen is required.

In 1997, the first hints of ancient crust were discovered at Assean Lake. This discovery has led to extensive research in the Assean Lake area and the adjacent crustal domains of the Superior Boundary Zone. The Assean Lake ancient crust comprises a collage of Archean crustal segments, trending approximately 090–110°, that are overprinted by Neoarchean and Paleoproterozoic deformation and metamorphism trending 060°. The Assean Lake crustal complex is subdivided into 1) a southern, migmatitic, supracrustal series of quartz arenite, arkose, and metagreywacke gneiss, containing amphibolite and silicate-facies iron-formation, and 2) a central, orthogneiss-dominated crustal segment that intrudes 3) a northern package of supracrustal rocks dominated by mafic to intermediate metavolcanic rocks and greywacke gneiss. Combined Sm-Nd isotopic and U-Pb geochronological results, obtained using thermal-ionization mass spectrometry (TIMS) and sensitive high-resolution ion microprobe (SHRIMP), indicate that Assean Lake preserves Paleoarchean to Mesoarchean crust that underwent a complex and prolonged history spanning more than two billion years.

SOUTHEASTERN MANITOBA

Regional Mapping in Southeastern Manitoba

A collaborative GSC–MGS mapping program in the Black Island area of southeastern Lake Winnipeg was conducted under the auspices of the Western Superior NATMAP project. Initial reconnaissance studies were completed in 1999. The mapping was undertaken to characterize the nature of the boundary between two important tectonic elements of the western Superior Province, the North Caribou Terrane and the Uchi Subprovince. In the Black Island area, the margin of the ca. 3.0 Ga North Caribou Terrane is overlain by a quartzite–carbonate–iron-formation–komatiite sequence that records pre-2.92 Ga rifting of this protocontinent. Younger, Neoarchean volcanic rocks (mainly basalt and basaltic andesite) of the Uchi Subprovince were structurally juxtaposed against this margin in a ca. 2.72 Ga strike-slip regime. A succession of arkose and conglomerate containing detrital zircons as young as 2706 Ma was deposited in strike-slip basins during continued early oblique convergence. Waning deformation became focused in shear zones during subsequent transcurrent shear events. Elucidation of the complex structural history along the boundary of the Uchi Subprovince and North Caribou Terrane at the west end of the Rice Lake greenstone belt provides a much-improved geological context in which to conduct exploration activities.

PGE Studies

The Bird River Sill has historically been explored for chromite, Ni-Cu and platinum-group elements (PGE). The recent increases in both price and demand for PGE led to renewed interest in the Bird River Sill. Work this year on the Chrome property has defined a sulphide- and PGE-bearing layer hosted by highly deformed peridotite. This new PGE exploration prospect is in addition to two previously defined PGE-bearing layers associated with chromitite units. On the Page property, located about 2.5 km northeast of the Chrome property, new work has also defined a sulphide-bearing peridotite layer associated with chromitite units. This chromite- and PGE-bearing layer has a stratigraphic position analogous to those on the Chrome property.

Phytoremediation of Mine Tailings

A new project to establish the trace-element content of abandoned mine-site tailings, the potential for phytoremediation of these sites, and an assessment of the production of bio-ores through the identification of hyperaccumulator plant species has been initiated at the Central Manitoba (Au) mine site in southeastern Manitoba. The first phase of this project has established the trace-element characteristics of tailings at the mine site through multi-element analysis of samples collected from three, 1 m deep, hand-augured profiles. Results indicate that a partial

extraction at pH 2–3 liberates a wide range of base and precious metals from the tailings at the mine site, and that these metals provide the focus for the future development of a bio-ore. Ten plant species were planted on three experimental sites on mine tailings. The survival rate and amount of extracted base and precious metals should indicate plant species suitable for phytoremediation and phyto-extraction.

SOUTHERN AND CENTRAL MANITOBA

The MGS continues to promote exploration and development opportunities for specialty and nonmetallic minerals, both on the Precambrian Shield and in the Phanerozoic-covered portions of south-central Manitoba. The increasing evidence for post-Precambrian structural movements within the buried portions of the Superior Boundary Zone–Thompson Nickel Belt has provided a unifying theme for a number of features within the Phanerozoic section in west-central Manitoba.

Regional Investigations in the Interlake Region

The Camperville area of the Interlake region contains a large (65 km diameter) semicircular gravity anomaly of approximately 30 mGal, the most intense negative gravity anomaly in Manitoba. In the spring and summer of 2000, reconnaissance gravity surveys and follow-up detailed gravity and magnetic surveys were carried out along a line, from Camperville, Manitoba to the Saskatchewan border, that transected the gravity low. The Camperville anomaly is adjacent to the sub-Phanerozoic extension of the Thompson Nickel Belt and is apparently truncated on the northwest by a major fault defining the eastern edge of the TNB. Other recent studies have concluded that the Superior Boundary Zone has been active during the Paleozoic. Such late structures may have produced channelways for deep fluid migration from the buried Precambrian basement through the overlying Phanerozoic strata, and could have left their signature by depositing minerals at structural and lithological traps. Geochemical anomalies and the presence of sphalerite in drillholes penetrating Devonian formations in this region suggest that such fluid migration and mineralization may indeed have taken place during the Phanerozoic.

Saline spring waters have been sampled along the west shore of Lake Winnipegosis. Preliminary results suggest that Pleistocene glaciation had a significant impact on the regional flow system of the Paleozoic aquifers in the area.

Phanerozoic Stratigraphic Investigations

Stratigraphic investigations and drilling programs were carried out for various projects in south-central Manitoba. The Capital Region Project has been completed and is in the editing stage. H.R. McCabe's historical corehole data have been added to the Manitoba Stratigraphic Database. All brine springs are being tabulated for the Prairie-type Project. Two coreholes were drilled in the Dancing Point (Lake Winnipeg) area for stratigraphic purposes; one corehole was drilled proximal to the High Rock Lake structure; one corehole was drilled in the Wekusko area to test metallic veining in the Red River Formation; and one corehole was drilled in the Winnipegosis area for regional stratigraphy. A total of 457.8 m of drilling was conducted this year.

In 1999, the northern portion of the Capital Region Study was released as preliminary maps. In 2000, the study was extended to the south, and the maps and report are in the editing stage for the entire Capital Region Study, including the north and south halves. The Manitoba Stratigraphic Database (MSD) continues to be updated with the addition of historic tops to 437 wells.

Collaborative Projects in Southern Manitoba

As a contribution to the National Geoscience Mapping Program (NATMAP), the MGS and the GSC are co-operating in a program of geological mapping for the Winnipeg Region, with emphasis on engineering and environmental geology. Surficial mapping was completed in two phases for the area from 49° to 51°N and from 95° to 98°W. The current emphasis of the NATMAP and related MGS programs is on the completion of a three-dimensional (3D) digital geological model for all Phanerozoic sedimentary rocks and Quaternary deposits. This model will be completed first in the NATMAP area and subsequently for all of southern Manitoba. A number of data sets have been used to construct this 3D model: a digital elevation model (DEM), large lake bathymetry, offshore seismic surveys, surficial geology maps, lithological data for the Quaternary from water-well and other drillhole and geophysical databases, bedrock surface elevations, bedrock geology maps, Phanerozoic stratigraphic data and previous Phanerozoic models, and sub-Phanerozoic Precambrian geology maps. Completion of all project outputs is planned for March 2002.

The MGS and the GSC have initiated a multidisciplinary research program to reconstruct the pre-instrumental flood history of the Red River and to assess the importance of geological processes that may be increasing the flood hazard. The project is using a variety of geological and biological records to provide annual reconstructions of important hydroclimatic variables over the last several thousand years and provide a proxy record of high-magnitude floods in the Red River valley. The current tree-ring record, collected on a 100 km transect along the Red River, extends for 536 years from AD 1463 to 1999. This record contains anatomical signatures caused by Red River floods in 1950, 1852, 1826, 1811, 1778, 1747 and 1532. Complementary isotopic, chemical and ring-width records will be developed to evaluate the relationship between climatic conditions within the Red River drainage basin and the flood record of the Red River.

Aggregate Resource Studies

The MGS conducts aggregate-resource studies in southern Manitoba, work that contributes to the resource management and land-use planning decisions made by district planning boards. In 2000, 1:50 000 scale aggregate resource studies were conducted in the Rural Municipality of Cameron, covering eight townships in southwestern Manitoba near the town of Hartney. Gravel reserves (in two delta deposits) range from 3 m to more than 6 m in thickness and are composed of sand and gravel, with most of the reserves lying below the water table. Shale content of the gravel varies quite widely within the deposits; higher shale contents lower their economic value. Most of the aggregate produced comes from six active gravel pits and three shale quarries. The municipality is the greatest consumer of aggregate, mostly for road maintenance.

Land Use

The year 2000 marked the official end of the World Wildlife Fund Canada's Endangered Spaces Campaign. However, the provincial Protected Areas Initiative has been extended for three more years. This year, another 200 000 ha of the province were placed in protected status when Birch Island, Fisher Bay and Hudwin Lake Park reserves were designated in the spring. In addition, almost 40 000 ha of Wildlife Management Area lands were placed in protected status. Industry participation and consultation in the review of candidate sites for Manitoba's Network of Protected Areas provides Manitoba with increased certainty related to land-use issues.

NORTHERN MANITOBA

Industrial-Mineral Potential, Churchill

Precambrian and Phanerozoic bedrock outcrops and quarry locations in the Churchill area were inventoried during a brief visit to the region. Current production is mainly for aggregate and minor building stone. Although current production is considerably less than for most southern Manitoba localities, Churchill has potential for industrial-type

minerals because rail transportation costs would make alternatives prohibitively expensive. Future production may involve production of quartzite as a source of silica, rare elements from quartz veins and minor rock collecting. Unique fossils, such as trilobites, have been found along the shoreline of Hudson Bay. The largest recorded complete fossil of a trilobite ever found, a specimen 70 cm long by 30 cm wide, was collected from the Ordovician Churchill River Group on the tidal flat near Churchill in July 1998 by D. Rudkin of the Royal Ontario Museum.

GEOSCIENCE INFORMATION SERVICES

Compilation Maps

The Bedrock Geology Compilation Map Series (BGCMS) was initiated in 1985 to provide uniform 1:250 000 geological compilation maps for the entire province, initially focusing on areas of high mineral endowment and/or high mineral potential. Digitization of all existing manually drafted BGCMS maps is almost complete, and map production is now 100% digital, using ArcInfo™ GIS technology. There are now 29 BGCMS maps covering more than half of the province, including the entire Churchill Province, core areas of the Superior Province, and the capitol region of southern Manitoba. Those parts of Manitoba not yet covered by the BGCMS include areas of mainly unexposed Phanerozoic bedrock and portions of the Superior Province with little or no bedrock exposure or no supracrustal rocks.

Web-Enabled GIS Products

Web-enabled geographic information system (GIS) technology is a tool used to present geospatial data on the Internet. This technology provides the Internet client with twenty-four hour access to our department's information. To access the database, an Internet connection and a JAVA-enabled web browser such as Microsoft Internet Explorer™ or Netscape Navigator™ is required. The website has a user-friendly GIS style, with tools that allow query and analysis of the most current data sets relevant to the mining and mineral exploration community. The 'GIS Map Gallery', which is the access point for information on mineral claims, assessment files, orthophotography and geological databases, can be found at:

http://www.gov.mb.ca/em/geoscience/gis/gis-index.html.

CLIENT SERVICES

As a result of a departmental reorganization in August 2000, responsibility for the production and sale of technical reports reverted to the Geological Survey. The Client Services group is also responsible for the Library, a Divisional resource that is much used by the public.

February 2000 marked the first time the *Report of Activities* was posted to the Internet, on the departmental web site. Clients are able to download PDF files (for individual reports) from the web site at no cost and print pages identical to those in the hard-copy report. In the first six months following the posting of the *Report of Activities 1999*, there have been almost 2200 PDF files downloaded by clients, making this one of the most popular methods of report distribution. Further enhancements to the Geological Survey web site in 2000 included the introduction of web pages for a diverse range of topics:

- Paleofloods in the Red River Basin
- Preliminary exploration database for platinum-group elements in Manitoba (OF2000-5)
- Digital elevation model of southern Manitoba
- GIS map gallery

REGIONAL OFFICES

The Flin Flon regional office continues to supply a variety of services to the mineral exploration and mining communities active in the Flin Flon–Snow Lake region, including recording new mineral claims, maintaining an up-to-date library of provincial claim maps, dealing with claim status inquiries and accepting assessment-work submissions. Progress was made in the ongoing mines documentation project for the Flin Flon–Snow Lake region. Efforts are currently being directed toward completing several outstanding reports, including three volumes of the *Mineral Deposit Series*. The present staff in the Flin Flon office includes a Regional Geologist, a Resident Geologist and a Recording Clerk.

Staff in the Thompson regional office respond to a range of inquiries including regional geology, potential of mineral properties and mineral identifications. Thompson staff geologists are currently involved in a comprehensive multidisciplinary re-evaluation of the geology and mineral wealth of the Lynn Lake greenstone belt, the Thompson Nickel Belt and PGE potential in the Bird River sill. The Thompson office provides Mining Recording services to the community, including data on the status and registration of claims, access to and sales of maps and reports, and access to electronic databases.

DEPARTMENTAL INCENTIVE PROGRAMS

Departmental initiatives that foster a positive business climate for exploration and mining include the introduction of more favourable taxation policies, continuation of the Mineral Exploration Assistance Program (MEAP), the Prospectors Assistance Program (MPAP), and the new Specialty Minerals Incentive Program (SMIP), aimed at promoting development in the industrial-minerals sector.

Mineral Exploration Assistance Program (MEAP)

The purpose of the Mineral Exploration Assistance Program is to increase exploration and stimulate activities that may lead to the development of new mines in Manitoba. The program makes $2.75 million available in each of three fiscal years, beginning in 1999–2000.

MEAP will provide assistance for up to 25% of approved eligible exploration expenses, to a maximum of $300 000 per company per fiscal year. The program offers up to 35% of approved eligible expenses, to a maximum of $400 000 per company per fiscal year, for proposed projects in remote northern areas and in the Lynn Lake–Leaf Rapids area. Priority is given to grassroots or preliminary exploration (i.e. exploration not associated with a producing mine).

Since the inception of MEAP in the fall of 1995, 331 applications for assistance have been submitted. A total of $16.8 million in financial assistance has been allocated to 269 projects proposed by 76 companies. To date, the total amount of assistance issued is $8.2 million. Exploration expenditures in Manitoba are reported to be $36.0 million per year.

Prospectors Assistance Program (MPAP)

The Manitoba Prospectors Assistance Program offers grants to prospectors exploring on either their own properties or on open Crown mineral land in Manitoba. The program provides 50% of the eligible expenditures incurred by prospectors, up to $7500 per applicant per year. To qualify, applicants must hold a Manitoba Prospecting Licence, be experienced and self-employed, and have a prospecting project within Manitoba on mineral dispositions held by the applicant or on open Crown mineral land. Eligible expenditures include wages, subsistence, transportation, operating supplies, rental of equipment, assays, diamond drilling, and contractor and/or consulting services.

Applications for summer projects must be submitted between April 1 and May 15 of the year in which the project is to be carried out, or between November 1 and December 15 for winter projects. Since its inception in 1992, the program has processed 285 applications for assistance and paid out $744 148 in assistance funding to prospectors.

Specialty Minerals Incentive Program (SMIP)

The Specialty Minerals Incentive Program is designed to assist companies and individuals to evaluate the economic potential of existing specialty mineral deposits and market those resources more effectively. Funding of up to $500 000 was identified for SMIP, beginning August 3, 1999. The program will make $250 000 available for each of the 1999–2000 and 2000–2001 fiscal years.

SMIP provides financial assistance for up to 30% of approved eligible expenditures, to a maximum of $50 000 per applicant per fiscal year. The eligible commodities targeted by SMIP include, but are not limited to, amber, bentonite, kaolin, other clay minerals, gypsum, limestone, silica sand, coal, salt, shale, peat, dimensional stone, spodumene, chromite, talc, soapstone, feldspar, titanium, magnesium, beryl, ilmenite, potash, lignite and hematite. Minerals that are not eligible under SMIP include aggregates as they pertain to construction, base and precious metals, and oil and natural gas. Eligible expenditures include bulk sampling, definition drilling, geochemical analysis and assaying, feasibility and market studies (as they pertain to the resource), and testing of samples.

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