GS-29

GEOLOGY OF THE WINNIPEG REGION NATMAP PROJECT: 1999-2000 PROGRESS (NTS 62H/W, 62I AND 52L/W)

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SUMMARY

As a contribution to the National Geoscience Mapping Program (NATMAP), Manitoba Geological Survey (MGS) and Geological Survey of Canada (GSC) are co-operating in a program of geological mapping for the Winnipeg region, with emphasis on engineering and environmental geology. The surficial component of the NATMAP project was completed in two phases for the area from 49° to 51°N and from 95° to 98°W. In addition to completion of associated topical investigations, current emphasis is on compilation of the NATMAP outputs, and other co-operative GSC work in the area, into a synthesis. When combined with other MGS programs, such as the Capital Region Study, this synthesis will lead to generation of a three-dimensional (3-D) digital geological model for all deposits above the Precambrian, first in the NATMAP area and then for all Phanerozoic terrane in southern Manitoba. The inputs to this model include a digital elevation model, 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 maps, Phanerozoic stratigraphic data and previous Phanerozoic models, and sub-Phanerozoic Precambrian geological maps. Completion of all project outputs is planned for March 2002.

INTRODUCTION

The NATMAP program was established by Canada's federal, provincial, industry, and academic geoscience communities in 1990 to promote multidisciplinary, co-operative, computer-based programs of new geological mapping. These programs would include opportunities to address mineral-resource development, environmental and societal concerns, fundamental geological knowledge, and the training of student geologists in mapping procedures.

Under the Prairie NATMAP project, initiated in 1991, new 1:100 000 scale surficial geology maps were completed for areas southeast of Winnipeg, south of latitude 50°N and east of longitude 97°W (Matile et al., 1998). Under the current Winnipeg NATMAP project (1997–2001), similar mapping and glacial sediment sampling have been completed over an expanded area, south of latitude 51°N and east of longitude 98°W; release of the maps is pending.

The objectives of this expanded, Winnipeg Region NATMAP Project are to:

1) obtain an enhanced understanding of the environmental framework and geological history of the Winnipeg region, through the synthesis of available information and collection of new field data, and to communicate this knowledge to users, primarily in the form of new, computer-based geological maps;
2) make major strides in understanding geological features such as the Belair–Sandilands glaciofluvial complex;
3) further the establishment of a Winnipeg- and Ottawa-based infrastructure for the rapid production of high-quality, interactive, digital cartographic products;
4) support the training of field geologists in the production of new maps;
5) facilitate mineral exploration, particularly in the exposed Precambrian Shield east of the Winnipeg River, by producing new geological and geochemical maps of the area;
6) provide an upgraded information base designed to support construction and other engineering activity;
7) better define geological factors that control the quantity, quality and long-term sustainability of groundwater resources in the Winnipeg region;
8) support efforts to manage the Lake Winnipeg basin, by interpreting the evolution of the lake in recent geological time and the role played by geology in controlling shoreline erosion; and
9) support environmental and land-use management, by mapping the composition and extent of lithological units that are relevant to issues such as waste disposal, soil geochemistry, and vulnerability of aquifers to contamination.

Mapping of the study area is now being extended into the subsurface, using drillhole data and geophysical surveys, in order to obtain a 3-D model. The NATMAP results, combined with other programs of the Manitoba Geological Survey, including Phanerozoic stratigraphic investigations and the Capital Region Study, are now producing a geological model with many applications, from basic science to activity such as groundwater-flow modelling and industrial-mineral resource management. Key inputs to the synthesis are also being generated by the completion of offshore and shoreline surveys in Lake Winnipeg (Thorleifson et al., 1998a), regional hydrogeological investigations (Thorleifson et al., 1998b), and studies of the Red River and its flood history (Thorleifson et al., 1998c).

This paper focuses on progress toward a digital 3-D model for all materials above the Precambrian surface, initially for the NATMAP study area (lat. 49–51°N, long. 95–98°W), and subsequently for all Phanerozoic terrane in southern Manitoba.

THREE-DIMENSIONAL MODEL

Digital Elevation Model

A detailed digital elevation model (DEM) was required 1) as the surface from which the 3-D model will hang, 2) to vertically position sites in drillhole databases, and 3) to satisfy elevation-sensitive applications such as groundwater flow. Having built the DEM, however, it was found that the model provides profound insights into both known and previously unknown geological features. Detailed data were derived from Province of Manitoba orthophoto surveys for much of southern Manitoba (Matile and Keller, 1999), and the model is now in its second version (Keller and Matile, in prep.). In order to build an elevation model for all of southern Manitoba Phanerozoic terrane, additional data from National Topographic System (NTS) contour lines and elevation points, lake-surface elevations, and United States Geological Survey (USGS) elevation data were added to the second version of the provincial data, to extend the model to latitude 55°N (Pyne et al., in prep.). In

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order to facilitate correlation of Manitoba geology with that of adjacent areas, the DEM was extended into Saskatchewan to longitude 102°W, into Ontario to longitude 94°W, and into the United States to latitude 48°N. The resulting model (Fig. GS-29-1) has a grid resolution of 100 m, and absolute vertical accuracy of about ±3 m in southern Manitoba where detailed provincial data are available. Relative accuracy is on the order of tenths of a metre, based on the scale of features defined by the model. Outside this area, absolute accuracy varies, depending on the source of the data.

Bathymetry

A full 3-D geological model and its applications (e.g. interpretation of regional bedrock structure and groundwater flow modelling) require clarification of water depths and geometry of lake-bottom features. Bathymetric information is therefore required, at least for large lakes. Soundings reported on 22 Canadian Hydrographic Service charts for Lake Winnipeg, Lake Manitoba, Lake Winnipegosis, Playgreen Lake and southwestern Lake of the Woods (chart numbers 6211, 6240, 6241, 6243, 6247, 6248, 6249, 6251, 6258, 6259, 6260, 6263, 6264, 6267, 6268, 6270, 6271, 6272, 6273, 6274, 6505 and 6506) were therefore digitized, with sounding locations adjusted to positions relative to the shoreline, as defined by NTS 1:250 000 scale topographic maps (Matile and Keller, in prep.). The resulting database contains 31 607 soundings (Fig. GS-29-2). The shoreline was treated as a contour line, and point features depicting rocks and shoals on NTS 1:250 000 scale maps were treated as soundings set to lake level. All data were adjusted for reported chart datum and converted to lake-floor elevation and depth relative to mean lake level. The data have been modelled at a grid resolution of 100 m. The database and model are not intended for navigation.

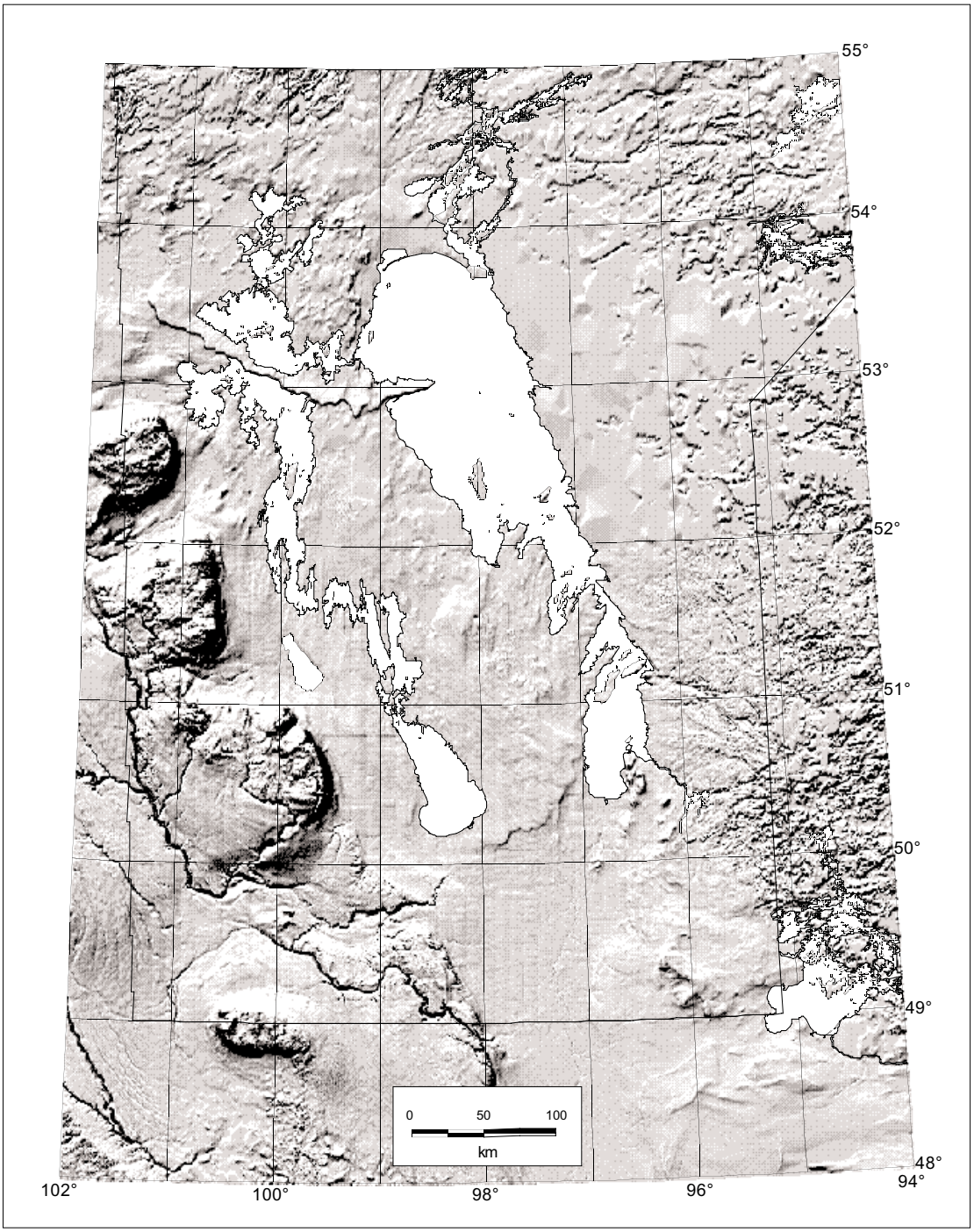

Figure GS-29-1: Shaded-relief depiction of the digital elevation model constructed for the project.

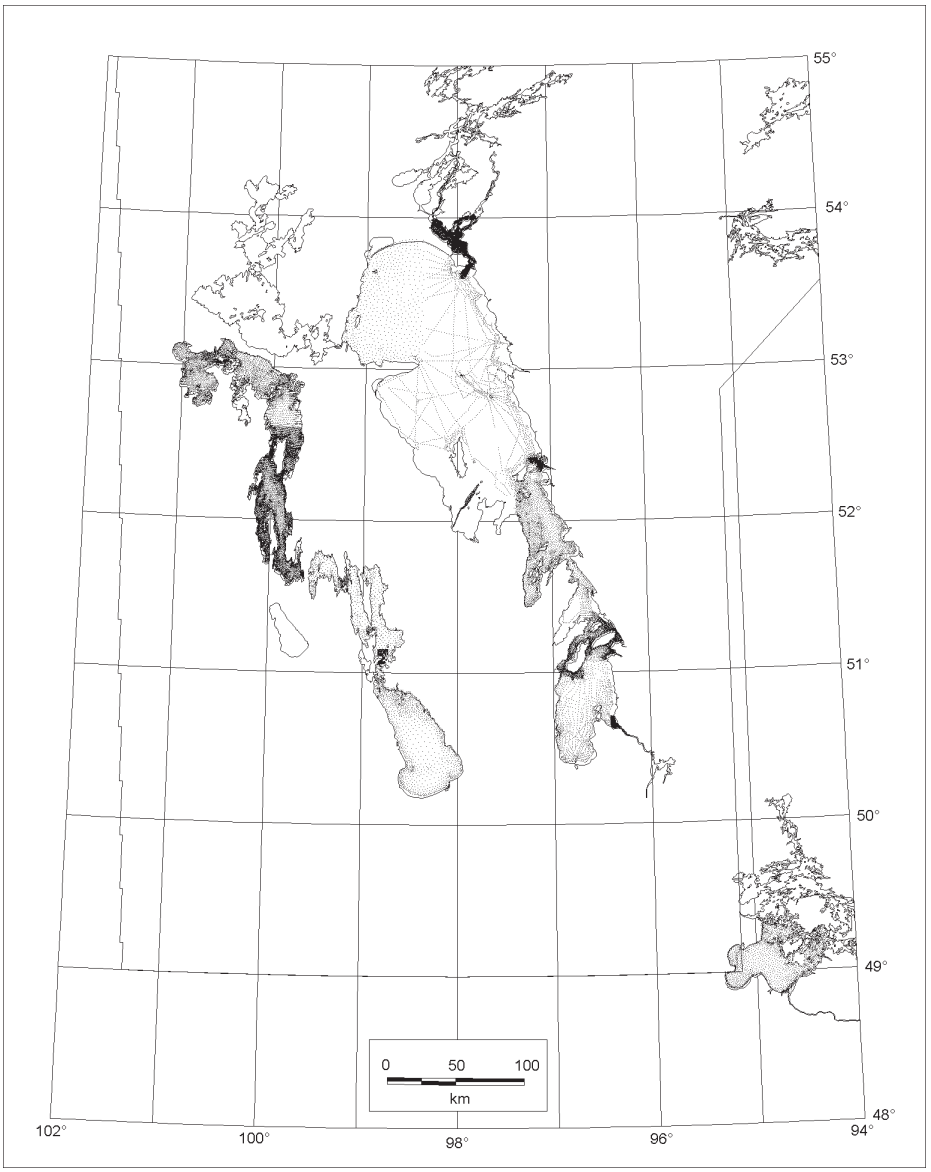

Figure GS-29-2: Location of bathymetric soundings digitized for the project.

Offshore Seismic Surveys

Fine-grained sediments, in places exceeding 100 m in thickness, occur in Lake Winnipeg (Todd et al., 1998, 2000). Similar sediments have been described in Lake Manitoba (Teller and Last, 1981). In order to model this infill in Lake Winnipeg, seismic data collected from the Canadian Coast Guard ship *Namao* in 1994 and 1996 (Todd et al., 1998, 2000; Fig. GS-29-3) are presently undergoing additional processing in order to define surfaces for top of Lake Winnipeg sediments (lake bottom), top of Lake Agassiz sediments, top of till and associated sediments, and top of bedrock. The model is being built with interpolations between seismic lines that are largely guided by bathymetric trends.

Surficial Geology Maps

Surficial geological mapping is used in investigations related to basic science, design and interpretation of geochemical surveys, environmental assessments, engineering applications (e.g. road construction, pipeline integrity, cabling and waste disposal) and management of industrial-mineral resources. It is also urgently required by the agricultural and water-resource sectors as a key layer of information regarding groundwater availability and vulnerability. Surficial geology is therefore an essential layer in the full 3-D model. For the detailed model of the NATMAP study area, recently completed maps at a scale of 1:100 000 (Matile et al., 1998) are being used. Planning is underway for construction of consistent, readily accessible surficial geology for the remainder of southern Manitoba. This next-generation surficial mapping infrastructure will be built, as resources become available, by:

1) digitizing all published maps;
2) building legend equivalency tables in association with various national and international geoscience data-model initiatives;
3) edge-matching seamless 1:250 000 scale map coverage; and
4) generalizing this coverage to a new 1:1 000 000 scale map.

Quaternary Sediments

A model for the Quaternary sediment sequence is being built, largely with reference to the water-well database held by Manitoba Water Resources Branch (GWDrill), guided by surface topography and surficial geology. The model is being constructed using what could be regarded as colour lithological-data scatter plots that depict all drillhole data, in most cases many thousands of sites, within 5 km wide west-east swaths. These scatter plots permit the geologist to apply judgment by occasionally ignoring data based on suspect lithological descriptions or locations apparently in error. The geology is being interpreted using a legend that was built with reference to previous research in the area

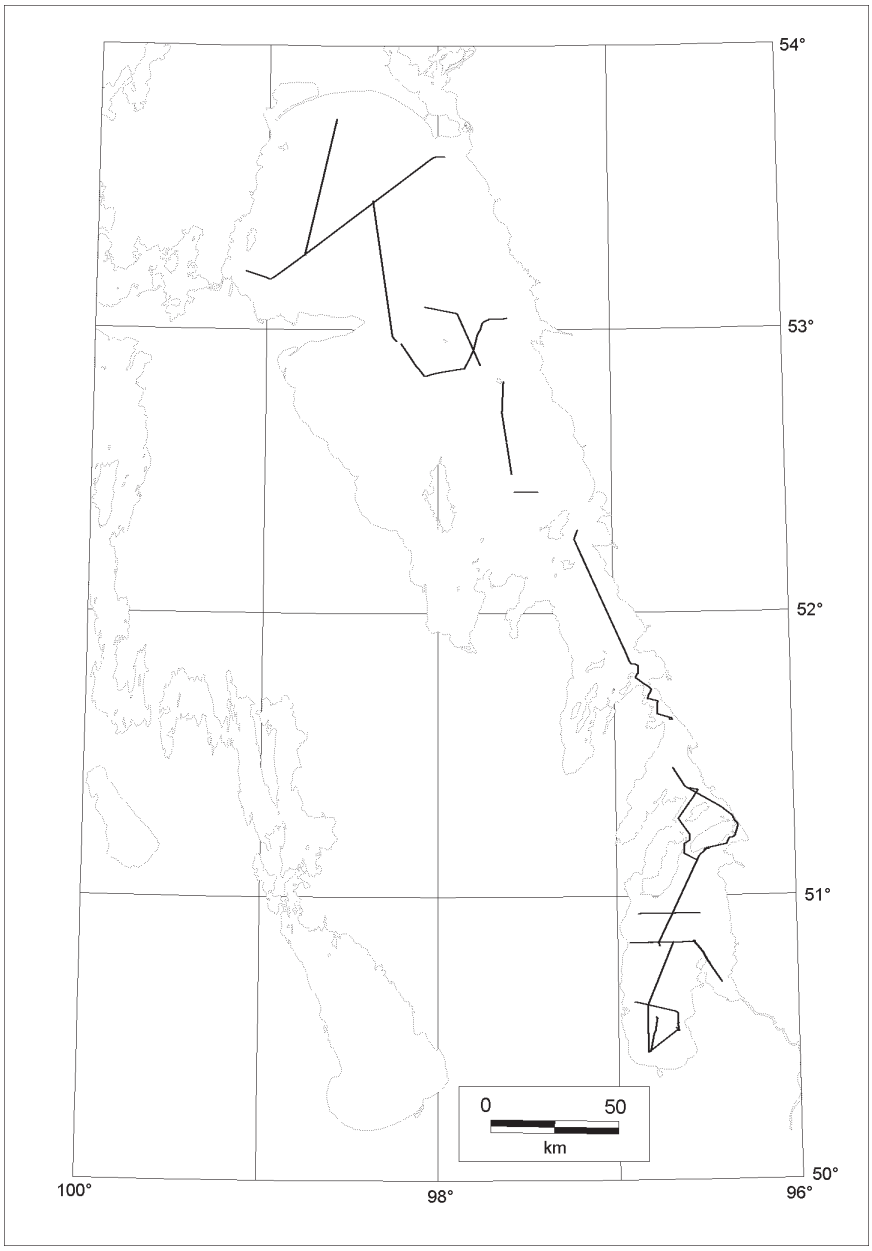

Figure GS-29-3: Location of offshore seismic lines.

(Teller and Fenton, 1980) and rotosonic coring carried out for the purpose of the project (Thorleifson and Matile, 1993). West-east geological cross-sections are being hand drawn, as an overlay on the water-well data. The interpretation is being captured as predicted stratigraphy points at a 5 km spacing, resulting in north-south sections, similar to the west-east fences (Fig. GS-29-4), that act as a check on the interpretation.

Bedrock Surface

A series of bedrock-surface topography maps has been produced by previous workers. These are being updated in association with modelling of the Quaternary sediment sequence.

Bedrock Maps

At present, the 1:1 000 000 scale bedrock geology map of Manitoba (Manitoba Department of Mines, Resources and Environmental Management, 1979) is being used to guide model construction. Plans are in place to increasingly use a complete, seamless Manitoba Geological Survey 1:250 000 scale coverage. Recent efforts, however, have been directed at converting the southern Manitoba Phanerozoic terrane portion of the existing 1:1 000 000 scale bedrock map from its former format to a new format in which polygons are extended over the full extent of the stratum, such that the 2-D model of each stratum can be digitally lifted off, to reveal what is below. This has required reference to previously published Manitoba Geological Survey stratigraphic charts (Bezys and Conley, 1999), as well as other literature that will be described in more detail upon completion of the model.

Phanerozoic Rocks

A complete digital model of the Phanerozoic sequence has been built from previously released Manitoba Geological Survey stratigraphic charts, with some reference to the Western Canada Sedimentary Basin Atlas (Mossop and Shetsen, 1994). The model has more units than were depicted in the database that accompanied the atlas, although fewer than are recognized in the Manitoba Geological Survey Stratigraphic Database, which includes many units only recognizable in limited areas. The current model has been assembled from structure maps for tops of units. Because these surfaces were modelled one at a time, the surfaces,

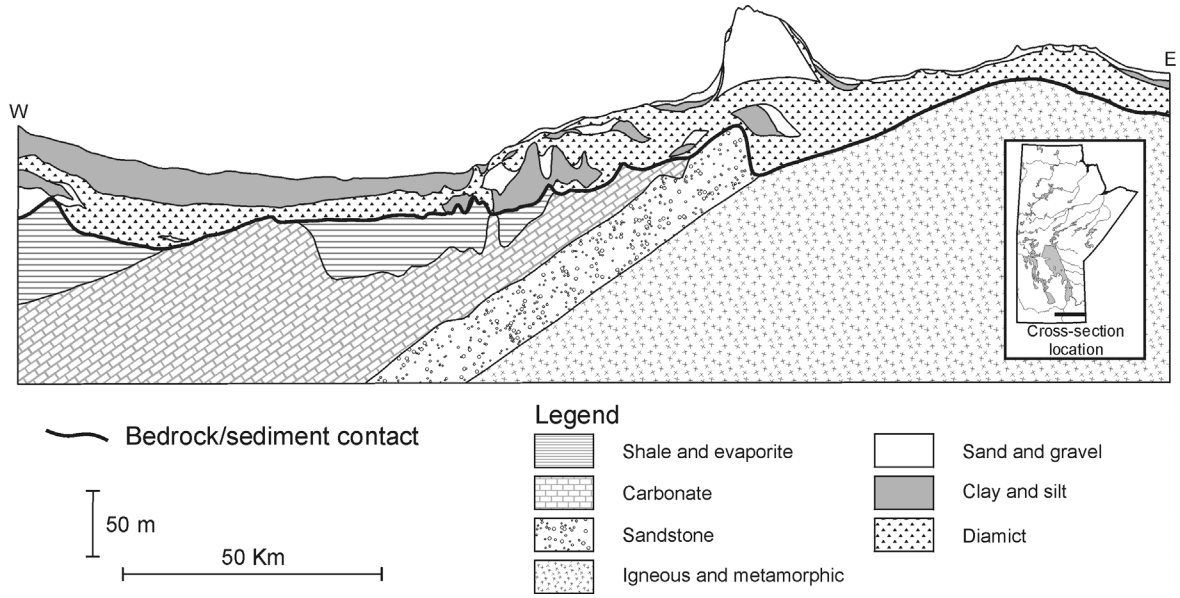

Figure GS-29-4: West-east geological cross-section of Quaternary sediments south of Winnipeg.

as would be expected, wander in data-poor areas. One result of this is that some strata have negative thicknesses in these data-poor areas. Construction of a new model is therefore being contemplated, using as much data as can be prepared in the time available, and with use of multiple surface-modelling procedures.

Sub-Phanerozoic Precambrian Geology Map

A preliminary sub-Phanerozoic Precambrian geology map for all of southern Manitoba Phanerozoic terrane has been prepared for the purpose of this exercise. This information has been compiled from various compilation maps, Project Cormorant and subsurface correlation of drilled Precambrian intervals.

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