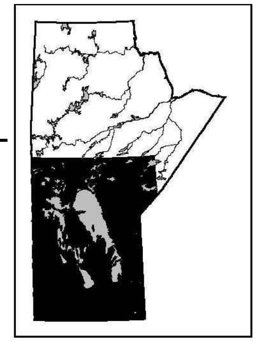

GS-23 CONSTRUCTION OF A THREE-DIMENSIONAL GEOLOGICAL MODEL FOR THE SOUTHERN MANITOBA PHANEROZOIC TERRANE

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SUMMARY

Nearly all of the one million inhabitants of Manitoba live in the 400 by 700 km area of Phanerozoic terrane in the southern portion of the province. The majority live in the Winnipeg area, a 200 by 230 km area in the southeastern corner of the province. Winnipeg obtains water from Shoal Lake, but the 200 000 residents of surrounding areas rely on groundwater obtained from bedrock aquifers. Fresh water in these aquifers consists of modern recharge and relict subglacial recharge, but a saline-water system recharged in South Dakota and Montana discharges to the western Red River valley. Research on the long-term sustainability of the fresh groundwater resource is addressing the protection of recharge, and ensuring that excessive pumping does not lead to unacceptable lateral migration of the saline waters. Three-dimensional (3-D) modelling is a key element of this strategy, and a geological model is required. The 3-D model will have many applications, from basic science to groundwater-flow modelling and livestock management.

The intention is to construct a 3-D geological model for the Phanerozoic terrane of southern Manitoba, south of latitude 55°N and west of longitude 95°W. The Phanerozoic sequence, comprising Quaternary sediments and Phanerozoic sedimentary rocks, down to and including the Precambrian surface will be modelled. This will require the acquisition of all readily available, nonconfidential drillhole databases in a format that can easily be utilized in a geographic information system (GIS).

CONSTRUCTION OF A THREE-DIMENSIONAL GEOLOGICAL MODEL

Construction of a three-dimensional (3-D) model for the southern Manitoba Phanerozoic terrane requires progress in three major areas: 1) digitizing of maps required for the Manitoba Surficial Geology seamless 1:250 000 scale map compilation; 2) surficial mapping of areas that have not previously been mapped at a sufficient scale, and 3) 3-D mapping of all stratigraphic units.

Digitizing of Maps Required for the Manitoba Surficial Geology Seamless 1:250 000 Scale Map Compilation

There are 54 NTS map sheets in the province. Sources of published surficial geology maps are the Manitoba Mines Branch, the Geological Survey of Canada (GSC) and digital maps (GSC and joint GSC–MGS). Portions of four NTS 1:250 000 scale map sheets (approximately six half sheets) require original mapping.

To date, all Manitoba government surficial geological maps required for the seamless 1:250 000 compilations have been digitized (covering portions of five 1:250 000 scale map sheets). Seven GSC 1:250 000 scale maps have been digitized. This covers much of the farmland in Manitoba, but leaves another five GSC 1:250 000 scale maps still to be digitized. Approximately five and a half NTS 1:250 000 scale map sheets are already in digital format; these maps are all at 1:100 000 scale and will require some degree of simplification. Automated procedures are being developed to simplify 1:100 000 scale polygons to achieve a level of detail appropriate for both 1:1 000 000 scale and 1:250 000 scale compilations.

All digitized maps will require edge matching. There are blocks of map sheets, particularly in the north, that have been mapped by a single GSC geologist and will hopefully require little or no edge matching. However, at the other end of the spectrum, some areas will require field checking and possibly supplemental mapping.

In addition to edge matching, the individual map sheets will have to conform to a standardized terminology. Every legend item has been parsed into a standard set of descriptors (i.e., a data model), which includes variables such as genesis, lithology and morphology. When the resultant database, which contains the parsed legend items, is combined with the digitized map polygons, the result will be a digital map that can be queried and displayed, based on a number of different criteria that depend on user requirements.

Surficial Mapping (NTS 52M, 62J, 62O and 62P)

Portions of NTS 52M (Carroll Lake), 62J (Neepawa), 62O (Dauphin Lake) and 62P (Hecla) require new surficial geological mapping. This area was mapped by Johnston (1931) at a scale of 1:506 880, but this is not a sufficient level of detail. The northestern half of 62O has been mapped by Nielsen and Matile (1985), and minor portions of 52M and 62P have been mapped by Groom (1985), Henderson and Way Nee (1998), and Henderson and Zdanowicz (1998). This leaves an area roughly equivalent to three NTS 1:250 000 scale map sheets that requires new mapping. The portion of this area lying west of Lake

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Winnipeg could, in the short term, be filled with digital soils polygons that have recently been made available by Agriculture and Agri-Food Canada.

Three-Dimensional Modelling

A 3-D model for the sedimentary rocks of southern Manitoba, including important aquifers, was completed as a series of paper contour maps more than a decade ago. This information has been computerized, but enhancement of the model, using data collected since the time of the original compilation, will be required. Much more effort will, however, be required to complete 3-D mapping of the sediments. A pilot for this activity in the Winnipeg area has been partially completed, and a presentation of the methods and partial model at a 3-D mapping workshop in Illinois in April 2001 met with a favourable response (Fig. GS-23-1). A refined method to complete the remainder of populated areas of the province where subsurface information is available from drillhole databases is now in development. The pilot Winnipeg-area model will be complete in November 2001. Whereas the model of the sediments is complete, including the south basin of Lake Winnipeg, work remains to be done on the sedimentary rocks.

For the rest of southern Manitoba, the complete 3-D model of the sediments and sedimentary rocks will cover the area south of latitude 55°N and west of longitude 95°W. In order to plan completion of this 3-D model, this area has been divided into six 200 km wide regions, each measuring 2° of latitude by 3° of longitude. Completion of the pilot has taken more than 3 years, but the subsequent five phases will benefit from province-wide database preparation done in association with the pilot and the fact that the methods and experience are now in place. The current estimate is that 6 months of effort by an experienced geologist will be required for each of the remaining five regions. There will, however, be constraints associated with

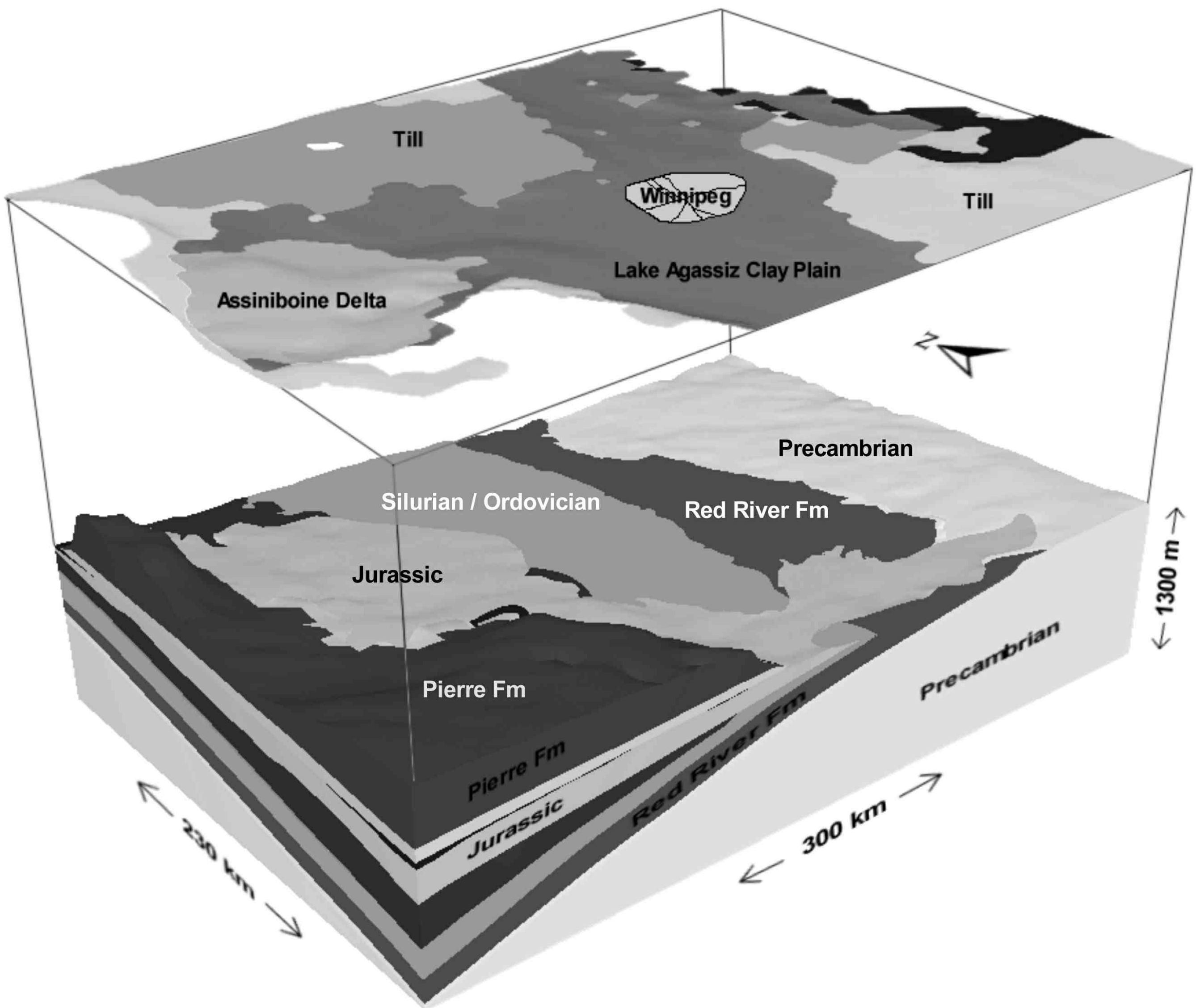

Figure GS-23-1: Simplified version of the 3-D model, covering an area from the Ontario border to approximately Brandon. This version of the model was developed for a groundwater-flow modelling thesis at the University of Manitoba. Quaternary sediments have been lifted off to show the rock surface.

unfamiliar geology, fewer wells and ambiguity in distinguishing shale and clay in southwestern Manitoba, and computing limitations as the study area increases in size. Construction of the complete model calls for full processing of multiple databases. The sedimentary rock data will be processed in the same manner as the data from water wells and coring that is being used for the sediments. The drillhole data will be linked to plan-view map data, using map-extent polygons that have been layered. Previously compiled elevation data for each sedimentary rock unit will be compared with the new data to determine extent of required revision.

The 3-D model is constructed using the following datasets (these datasets have generally been compiled for the entire region south of latitude 55°N):

Topography

Readily available topographic models have proven to be inadequate, so a new digital elevation model (DEM) was constructed from rectification data for digital orthophotography. Because the entire area was not covered by digital orthophotos, a surround for this data was compiled from topographic map contours and DEMs from neighboring jurisdictions. The resulting model has a grid resolution of 100 m, absolute vertical accuracy of about ±3 m and relative accuracy of less than a metre. The data have been used to position drillholes vertically, so the geological model hangs from the topography. The model has provided insight into previously unrecognized geological features.

Bathymetry

Large lakes occur in the area, including Lake Winnipeg. These are key features in the hydrogeological landscape, and lake-bottom features provide insights into geology. Soundings from 22 hydrographic charts were therefore digitized and a database containing 31 607 digitized bathymetry points was created. These were modelled with shoreline data and locations of shoals, at a grid resolution of 100 m.

Surficial geology

Subsurface modelling is guided by the most detailed available surficial geological mapping. At this stage, the subsurface model is not linked to the polygons, due to the much greater detail of the surficial geological mapping relative to the resolution that could be achieved in the subsurface.

Quaternary stratigraphy

Key inputs to the 3-D model of the sediments were cored holes logged by geologists, and geophysical surveys. These high-quality results were extrapolated laterally using water-well data from 80 000 sites (obtained from GWDrill, the water-well database maintained by the Water Branch of Manitoba Conservation). Much effort was required to parse the 75 000 unique lithological descriptions in this database. Also, before this database could be used in a GIS environment, x-y coordinates were assigned using quarter-section centroids and elevations from the DEM. The 200 by 230 km Winnipeg region NATMAP area (the pilot area) was divided into 46 transects, each 5 km wide, and a large colour chart was printed for each transect, showing all drillhole data, surficial geology and surface elevations. The drillhole data, colour-coded for lithology, were interpreted as a series of vertical maps using the same methods used to compile plan-view maps. The interpretation was captured as a set of virtual drillholes at 5 km spacing, and individual units were gridded using MapInfo and Gemcom.

Sub-bottom seismic data from Lake Winnipeg have been utilized much like a series of drillholes. The south basin has been modelled and the north basin will be modelled during subsequent modelling phases. Not only will this provide us with a better understanding of the Quaternary geology of the area, both onshore and offshore, but it will better define the Paleozoic limit within the lake.

Bedrock geology

A new set of 1:1 000 000 scale bedrock polygons for the Phanerozoic units was constructed, linking outcrop to subcrop, to produce stacked polygons. Structure contours, from the Stratigraphic Map Series, for each Phanerozoic unit were gridded and these grids clipped with the set of stacked polygons.

The plan is to update this model and, in so doing, provide an audit on the Phanerozoic stratigraphic databases. Presently, three of four databases containing Phanerozoic stratigraphy have been reformatted to be used in a GIS environment. They are the Manitoba Stratigraphic Database (MSD), the Manitoba Oil and Gas Well Information System (MOGWIS) and the Western Canada Sedimentary Basin database (WCSB). The fourth database, which is being called Index Cards, should be ready shortly. Some additional rock information will be gleaned from GWDrill. All of these data will be plotted on transects and handled much like the Quaternary stratigraphic data.

Once completed, the 3-D model will provide a repository of all readily available nonconfidential drillhole data for the area. As such, the model will provide an ideal means of deriving drilling targets for the MSD, which is an ongoing program.

In addition, data-poor areas in Quaternary sediments, Phanerozoic sedimentary rocks or Precambrian igneous rocks will be easily recognized, thus providing targets for future drilling. Capturing the 3-D model at 5 km spacing is likely too coarse for some applications, but is manageable at the current staffing level and with available computing power. In the future, we may want to consider refining the model to 2.5 or even 1 km spacing.

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