Regional geoscience database for the Oak Ridges Moraine project (southern Ontario)[1]

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Abstract:
To assist in completing surface and subsurface mapping in the Oak Ridges Moraine area a geoscience database is being developed. The database consists of three data storage elements: a) relational database, b) GIS layers, and c) flat files. The relational database is the repository for new and archival point data obtained by mapping and borehole studies. The GIS layers include a library of remotely sensed imagery, a regional Digital Elevation Model, and thematic layers. The flat file format has been used for subsurface geophysical data, particularly reflection seismic and ground penetrating radar profiles. Most of the database is on desktop PC platforms with UNIX systems being incorporated for specific tasks. A simple example is provided to illustrate the potential for database querying and spatial interpolation in a GIS.

Résumé :
Une base de données géoscientifiques est élaborée dans le but d'aider à la finalisation de la cartographie des dépôts en surface et en subsurface dans la région de la moraine d'Oak Ridges. Elle se compose de trois éléments : a) une base de données relationnelles, b) des couches de données intégrées à un système d'information géographique (SIG) et c) des fichiers plats. La base de données relationnelles sert à stocker toutes les données ponctuelles, tant les nouvelles que les anciennes, obtenues dans le cadre des travaux de cartographie et de forage. Le SIG comprend une imagethèque de télédétection, un modèle altimétrique numérique à l'échelle régionale et des couches thématiques. Le format «fichier plat» est utilisé pour consigner les données géophysiques souterraines, en particulier les profils de sismique réflexion et de géoradar. La base de données est en grande partie sur des ordinateurs personnels et le système d'exploitation UNIX permet d'effectuer des tâches spécifiques. Un exemple simple est présenté pour illustrer le potentiel qu'offre la base de données pour la consultation et l'interpolation spatiale dans un SIG.

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INTRODUCTION

The Oak Ridges Moraine NATMAP Project was initiated in the spring of 1993 as a collaborative multi-agency multidisciplinary project with the Ontario Geological Survey (OGS). The project is a response to the need for a better understanding of the regional geology and groundwater resources in an area of intense urban growth. The absence of a regional geological understanding was highlighted at the time by the Interim Waste Authority (IWA) search for waste disposal sites in the Greater Toronto Area and by the Oak Ridges Moraine Technical Working Committee of the Ontario Ministry of Natural Resources (MNR).

The Oak Ridges Moraine area provides interesting challenges for geological mapping. In most regions of the country mapping is completed primarily for mineral resource assessment. In contrast, issues in the Oak Ridges Moraine are related to urbanization: water resources – extraction, protection; land use – agriculture, real estate development, golf courses, waste disposal; and planning and development – urban expansion, aggregate extraction, shoreline erosion. The thick Quaternary sediments are being mapped both at the surface and in the subsurface to define the sedimentary architecture and stratigraphic succession. Understanding the three dimensional geological architecture will provide the basis for delineating the extent of aquifers in the area. To achieve these objectives the project initiated a comprehensive database development (T.A. Brennand, D.R. Sharpe, H.A.J. Russell, and C. Logan, 1994: poster H9 presented at 1994 Ontario Mines and Mineral Symposium, Toronto, Ontario).

This paper provides an overview of the project objectives in establishing the database. The computer platforms and software used are briefly discussed. The database structure is defined and data sets are reviewed. To demonstrate the application of the database, a regional drift thickness map has been generated from a database query in a GIS.

DATABASE OBJECTIVES

The GSC has been a leader in the collection, transfer, and dissemination of digital geoscience information in Canada since the mid-1970s (Belanger, 1975; Belanger and Harrison, 1980). Digital databases are now a standard component of geological projects at the GSC (Broome et al., 1993; Woodsworth and Ricketts, 1994; Harris et al., 1995; Belanger, in press). In the Greater Toronto Area there are a number of Urban geology databases (e.g., Oshawa; Brennand, in press) which were compiled by the GSC UGAIS (Urban Geology Automated Information System) project (Belanger, 1975). With increasing improvements in PC/desktop technology and the evolving nature of software, particularly GIS, databases have evolved from single component relational databases (e.g., Belanger, 1975) to multicomponent GIS projects (Bonham-Carter, 1989; Broome et al., 1993). The Oak Ridges Moraine database is a synthesis of relational database and GIS as the project attempts to integrate large three-dimensional data sets (T.A. Brennand, D.R. Sharpe, H.A.J. Russell, and C. Logan, 1994: poster H9 presented at 1994 Ontario Mines and Mineral Symposium, Toronto, Ontario; Brennand, in press). To meet the geological objectives and to disseminate the collected information to the largest possible user group, the principal database objectives are:

1. Create an integrated GIS database for geological analysis on PC based platforms.
2. Create an integrated geographically keyed digital geoscience database for the Oak Ridges Moraine area.
3. Complete spatial data analysis and map production in a GIS.
4. Package digital data in a format which can be distributed to, and easily accessed, by investigators in a broad range of science, engineering, and planning disciplines.

THE STUDY AREA

The study area comprises eight 1:50 000 scale National Topographic System (NTS) map sheets north of Lake Ontario, representing approximately 63% of the Greater Toronto Area (GTA). The Quaternary geology comprises a glaciolacustrine-glaciofluvial sequence which is divided into stratigraphic units by a regional till sheet and unconformities (Sharpe et al., 1994; Sharpe et al., 1996). The sediment is up to 200 m thick in the west and generally thins towards the east. The western margin of the survey area coincides with the Niagara Escarpment. The east-trending Oak Ridges Moraine forms the major landform element of the study area and defines the drainage divide between Lake Ontario and Georgian Bay drainage basins (Fig. 1).

DATABASE PLATFORM

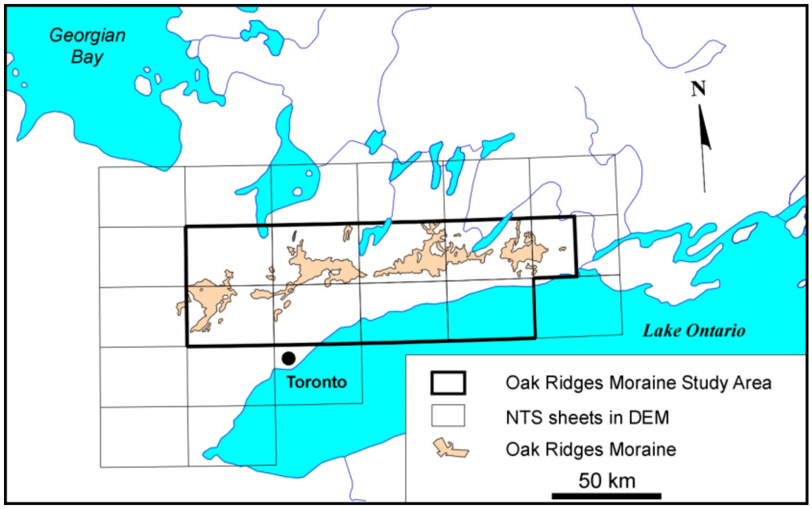

Figure 1. *Location diagram of the study area in southern Ontario*

The database has been developed around two computer software/hardware combinations. The relational database is supported by Microsoft Access and shared on a Local Area Network (LAN) using Windows/Windows NT based PCs. The GIS database has been developed on PC based MapInfo software and in unison on UNIX based ArcInfo and PCI systems. Microsoft Access was chosen as the relational database management system (RDBMS) because it: permits multiple user connectivity on a LAN, has a flexible and easily designed user interface, provides for enforceable relational integrity, contains built-in Visual BASIC language, supports Open Database Connectivity (ODBC) format and the ability to share data with other Windows based applications that support Dynamic Data Exchange (DDE). The UNIX based systems are being employed to deal with study-wide data sets which have large file sizes (up to 350 megs) and/or where processing is computationally intensive (e.g., Landsat TM and RADARSAT imagery, DEM). Following processing and reclassification many of these map and image layers can be handled in MapInfo and other PC based programs.

A main objective of the database is to use this GIS database on a PC platform. MapInfo was selected because of its multi-platform capabilities (Windows, Apple, UNIX), ease of use, functionality, and low cost. As a vector based program MapInfo does not meet all the projects requirements. As a result, the GSC has collaborated with Northwood Geoscience Ltd. in the development of Vertical Mapper, a software package that enables point-to-area data transformations. Specifically, Vertical Mapper allows point data interpolation, contouring, DEM generation, DEM perspective viewing, and some modelling.

THE ORM DATABASE STRUCTURE

The project has collected a geographically keyed data set and developed a database comprised of three data storage formats (Fig. 2): a) a relational database, b) a spatial GIS data set, and c) a flat file data format.

Relational database

The relational database management system contains point data which possess multiple attributes. To date the database contains seven principal tables linked by index fields (key fields) (Fig. 2). The common field linking all tables is “site number”. This field is the primary key field in the header table and is part of multiple-field primary keys or “foreign keys” in the other tables (see Microsoft Corporation, 1994). Data retrieval is achieved through the Microsoft Access query forum, or Microsoft Access BASIC.

GIS data layer

This component represents spatial data of either a vector or raster model. The data are stored as a library of layers in ArcInfo and MapInfo, and can be queried or compared with other data sets within a GIS. There are no direct-map-to-database relations as in some ArcInfo-Oracle database combinations (Broome et al., 1993).

Flat file data

This data set contains geophysical data, seismic, ground-penetrating radar profiles (GPR) and borehole geophysics data. The bulk of the data reside in proprietary file formats and are managed within DOS, Windows, or appropriate data processing packages.

DATA CAPTURE

Data capture involves both the transfer of reported data (e.g. geological, geotechnical, etc.), drilling information (e.g. type of drilling, company), and location information (e.g. geographic co-ordinates, etc.) to the database. Data has been transferred to the database by digital transfer (Ministry of Energy and Environment (MOEE) waterwell data, location data) and by manual entry (all geotechnical site investigation descriptions). Manual keyboard entry of hardcopy data files is the most time-consuming task of the database assembly and a potential source of error. To maximize data entry efficiency, data entry forms with links between database tables were created. The enforcement of data type restrictions and obligatory fields minimizes data entry errors. Subsequent data verification is an important task in the database development.

Data within the database must be georeferenced. This has proven to be a problem for a number of the data sets. It is not uncommon for reports to lack geographic coordinates, to have site maps with no geographic coordinates, or to have incorrect geographic coordinates on site maps and in the tabulated data. When necessary, geographic coordinates are obtained from site location maps by georeferencing identifiable points and digitizing or scanning site plans. Where the datum is not stated explicitly the availability of both North American Datum (NAD) 27 and 83 has increased the source of error in defining geographic coordinates. While the project has adopted the NAD 83 datum for output, it is critical that the datum of the original source is known to enable co-ordinate transformations. Where site location data can not be determined the data are not entered in the database.

Descriptions of geological materials in the archival data have been completed by a large number of people over a long period of time (>30 years). To ensure meaningful comparisons and to facilitate entry of sediment descriptions, two coding schemes have been developed. Sediment descriptions in reports have been entered using an adjective noun sequence (e.g. sandy silty diamicton), where the first descriptor is subordinate to each successive descriptor. The second coding system has two components, a material code and a preliminary unit attribute. The material coding system has ten generic, nonstratigraphic groupings (e.g. gravel, sand). The preliminary unit attribute coding has eleven genetic units (e.g. glaciofluvial, glaciolacustrine) . The application of the second coding system has ensured a standard sediment description regardless of data sets and an easily managed number of units which are common to the archival borehole and Oak Ridges Moraine field mapping.

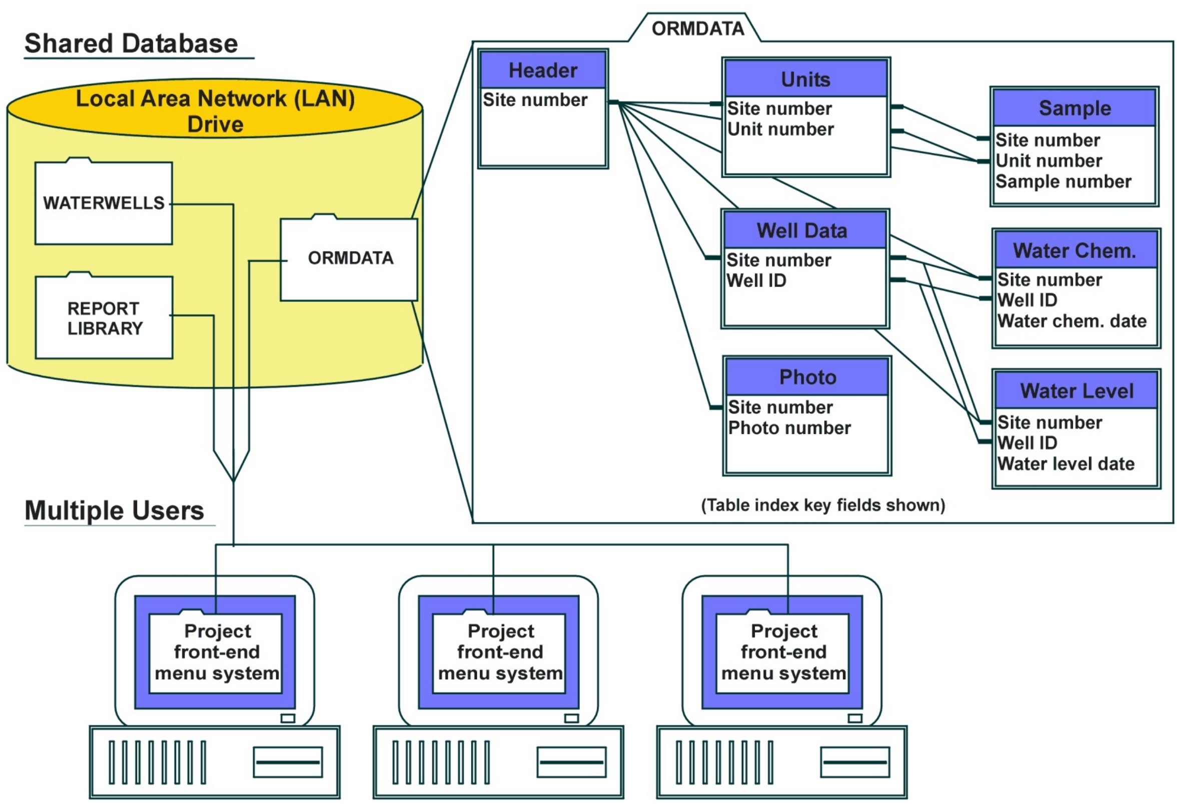

Figure 2. *Relational Database Structure*

DATA SOURCES

Archival and new data are being compiled in the database (Table 1, 2, 3). Data collected as part of the current program have been obtained by surveys completed by the GSC, OGS, Canadian Centre for Remote Sensing, and Provincial Remote Sensing Office. Archival data have been obtained from a range of government agencies (MOEE, Metro Toronto Conservation Authority, Ministry of Transport, Metro Toronto, and Municipalities of York, Peel, and Durham), Universities (Guelph), and the private sector (Consumers Gas, Canadian National Railway). Archival data can include hardcopy reports, digital file formats, and sediment cores.

Point data

Field data have been collected in support of the geological mapping program. These data include sedimentological and geochemical information from shallow (1 m) probe holes and road side excavations and deeper (1 to 25 m) river and lake shore sections (Table 1). Hydrogeological field data have also been collected along streams where baseflow discharge has been measured to determine the spatial distribution of groundwater discharge (Hinton, in press).

Table 1. Listing of data sources, nature of data, and summary information, (modified from Brennand, in press).

		NATMAP Field Sites	OGS Field Sites	NATMAP/ OGS BH	IWA	LaidLaw	LLRWMO	STFS	MTO	Misc. Geotechnical	Oshawa UGAIS	U. Guelph	MOEE
Geographic Location		■	■	■	■	■	■	■	■	■	■	■	■
Site Description		■	■	■	■	■	■	■	■	■		■	
Soil Description		■											
Sediment Description	Depth Interval	■	■	■	■	■	■	■	■	■	■	■	■
	Texture	■	■	■	■	■	■	■	■	■	■	■	■
	Colour	■	■	■	■	■	■	■	■	■	■	■	
	Structure	■	■	■	■	■	■	■	■	■	■	■	
	Contacts	■	■	■	■	■	■	■	■				
	Paleoflows	■	■	■	■								
	Clast Lithology	■	■	■	■								
Sample Type	Geotechnical					■	■	■	■				
	Geochemical	■		■	■								
	Heavy Mineral	■		■									
	Organic	■	■	■	■								
Bedrock Description and Depth		■	■	■	■	■	■	■	■	■	■		■
Hydrogeology	Static Layers			■	■	■	■	■	■	■	■		■
	Peizometric Level			■	■	■	■	■					
	Hydraulic Conductivity			■	■								
	Water Chemistry	■			■								■
	Stream Gauging	■											
Data Format Aquired		Hardcopy	Hardcopy	Hardcopy	Hardcopy	Hardcopy	Hardcopy	Hardcopy	Hardcopy	Hardcopy	Digital	Hardcopy	Digital
Current Format		Digital	Digital	Digital	Digital	Digital	Digital	Digital	Digital	Digital	Digital	Digital	Digital
Number of Records, approximate counts		3000	4000	9	146	61	91	67	2000	100	3777	35	57,000
Location Problem Identified		No	Minor	No	No	No	No	No	Some	Some	Uncertain	No	Yes
Data Quality Questions		No	No	No	No	Uncertain	Uncertain	Uncertain	Uncertain	Uncertain	Uncertain	No	Yes

Legend : ■ Data Entered

Table 2. Listing of GIS data layers and summary information

Type	Format	Scale	Horixontal Resolution (m)	Source	Coverage
Anthropogenic	Vector	1:50 000 & 1:250 000	N/A	Geomatics Canada	Complete
Hydrology	Vector	1:50 000 & 1:250 000	N/A	Geomatics Canada	Complete
Topography	Vector	1:50 000 & 1:250 000	N/A	Geomatics Canada	Complete
Soils	Vector	1:64 000	N/A	AG Canada	Partial
Surficial Geology	Vector	1:1 000 000	N/A	OGS	Complete
Surficial Geology	Vector	1:50 000	N/A	Project	Complete
Bedrock Geology	Vector	1:1 000 000	N/A	OGS	Complete
Tunnel Channels	Vector	1:50 000	N/A	Project	Complete
Drainage Basins	Vector	1:50 000	N/A	Project	Complete
TM bands 2,3,4	Raster	1:50 000 & 1:250 000	30	CCRS/PRSO	Complete
SPOT	Raster	1:50 000	10	PRSO	Partial
ERS-1	Raster	1:50 000		PRSO	Partial
RadarSat	Raster	1:10 000	9 to 30	CCRS	Partial
Thermography	Hardcopy	1:50 000		PRSO	Partial
DEM	Raster	1:50 000	30	Project	Complete
DEM	Raster	1:250 000	?	MNR	Complete
Gravity	Raster	N/A	N/A	Project	Complete

Table 3. Listing of Flat File data and summary information

Type	Agency	Format	Quantity	Purpose
Seismic	GSC / IWA	TIF and SIG2	45km	Architecture & Stratigraphy
GPR	GSC	TIF and SSI	N/A	Architecture, Water Table
Em-34, 47	GSC	ASCII	N/A	Bedrock / Stratigraphy
Downhole	GSC / IWA	ASCII	10 holes	Physical Properties

The geochemistry survey comprises 412 A and C horizon sample pairs providing a baseline data set for the Greater Toronto Area. This survey provides the first regional geochemical sample set for the area and allows comparison of anthropogenic and geological signatures.

Field data from previous OGS mapping programs (e.g. Karrow, 1967; White, 1973; Gwyn and White, 1973; Sharpe, 1980a, b) have been provided to the project in hardcopy format. Data for seven map sheets (Bolton, Alliston, Markham, Brampton, Guelph, Trenton, and Toronto) collected by these surveys have been integrated into the database. The location of bedrock outcrops mapped by the OGS have been captured from the 1:50 000 scale bedrock geology maps (Telford, 1976a, b, c; Carson, 1980a, b, c) and bedrock topography maps (Holden et al., 1993a, b, c). Sedimentological data collected along the north shore of Lake Ontario has been provided by researchers from the University of Guelph and OGS (Brookfield et al., 1982; H. Gwyn, unpub. field notes 1976).

The borehole dataset can be separated into three categories on the basis of geological data quality: boreholes with continuous core recovery, borehole data from geotechnical reports, and MOEE waterwell database (Table 1). Boreholes with continuous core recovery provide the highest quality data and allow detailed sedimentological logging, which is crucial for the reliable interpretation of sedimentary processes and depositional environments. Continuously cored boreholes have been drilled by the GSC, OGS, and IWA. Borehole data from geotechnical reports have not been continuously sampled and have been described primarily for engineering purposes. While providing valuable information on sediment properties the descriptions have limited use for interpreting sedimentary processes. The waterwell data reported in the MOEE database have limited applications due to the absence of sediment sampling. The sediment descriptions rely on washings brought to the surface during the drilling process and do not describe solid sediment core. Individual boreholes from this data set have low reliability; however, as an ancillary data set and as a group, they are a useful subsurface mapping tool.

The GSC and OGS have drilled 10 boreholes with near continuous core recovery (>80%) These boreholes are providing detailed sedimentological data; hydrogeological data are being collected through the monitoring and sampling of nested piezometers (Table 1). The OGS has also contributed other drilling results, notably from the Woodbridge area (Kelly, 1994).

The IWA completed an extensive site specific drilling program within the three regional municipalities of the Greater Toronto Area (Durham, York, Peel) as part of a regional landfill search. This drilling program drilled nested sets of wells for hydrogeological monitoring, with depths ranging from 10 to 160 m. The project has entered data from published IWA reports (Interim Waste Authority 1993, 1994a, b, c, d, e). Following the termination of the IWA investigation in 1995 the GSC became the depository of approximately 6 km of IWA drill core from 140 boreholes. Relogging of some of this material is providing detailed sedimentological and stratigraphic information. The IWA has also provided access to the digital geological and hydrogeological data files retained by the respective consulting companies. This data set is of high quality and provides an unsurpassed examination of the geological conditions on a site basis (cf. Boyce et al., 1995). Data from similar site investigations have been obtained from the Port Hope area (unpub. report prepared for Low Level Radioactive Waste Management Office, by Gartner Lee Ltd., 1992) (Table 1).

Geotechnical boreholes are commonly drilled for site investigations of roads, bridges, railway crossings, gas pipelines, utility substations, hydro towers, lighting networks, and buildings prior to construction. This data set provides regional information on geotechnical parameters and water levels (Table 1). Boreholes of this data set are 5 to 30 m depth and include information on sediment texture, standard penetration testing ("N" values), grain size analysis, water levels, Atterberg limits, and shear strength.

The MOEE have provided the largest single data set to the project. For the Greater Toronto Area and peripheral areas there are approximately 57 000 boreholes (current to 1985). This data set is compiled by the MOEE through legislation requiring drillers to submit information on wells drilled. The data set provides a unique opportunity to expand sediment mapping regionally from sites of high quality data. This data set is particularly important for defining the bedrock surface as it is the only regional data set to reach bedrock. Each record contains information documenting location, sediment descriptions, well construction, and hydrogeological characteristics (Table 1).

Oak Ridges Moraine Database

Relational Database
- Point
  - **Geology**
    - Sediment Descriptions
    - Sample
      - grain size
      - geotechnical properties
      - geochemistry
  - **Hydro geology**
    - Water Levels
    - Discharge
    - Water Chemistry
    - Hydraulic Conductivity

GIS Data Layers
- Spatial
  - **Vector**
    - Polygonal
      - surficial geology maps
      - bedrock geology maps
      - soil maps
    - Linear
      - streams
      - lineaments
  - **Raster**
    - Digital Elevation Model
    - Remote Sensing
      - TM, bands 2,3,4
      - ERS-1
      - SPOT
      - RadarSat
    - Geophysics
      - gravity

Flat Files
- Geophysics
  - Seismic
  - GPR
  - Borehole

Figure 3. *Three components of the Oak Ridges Moraine database*

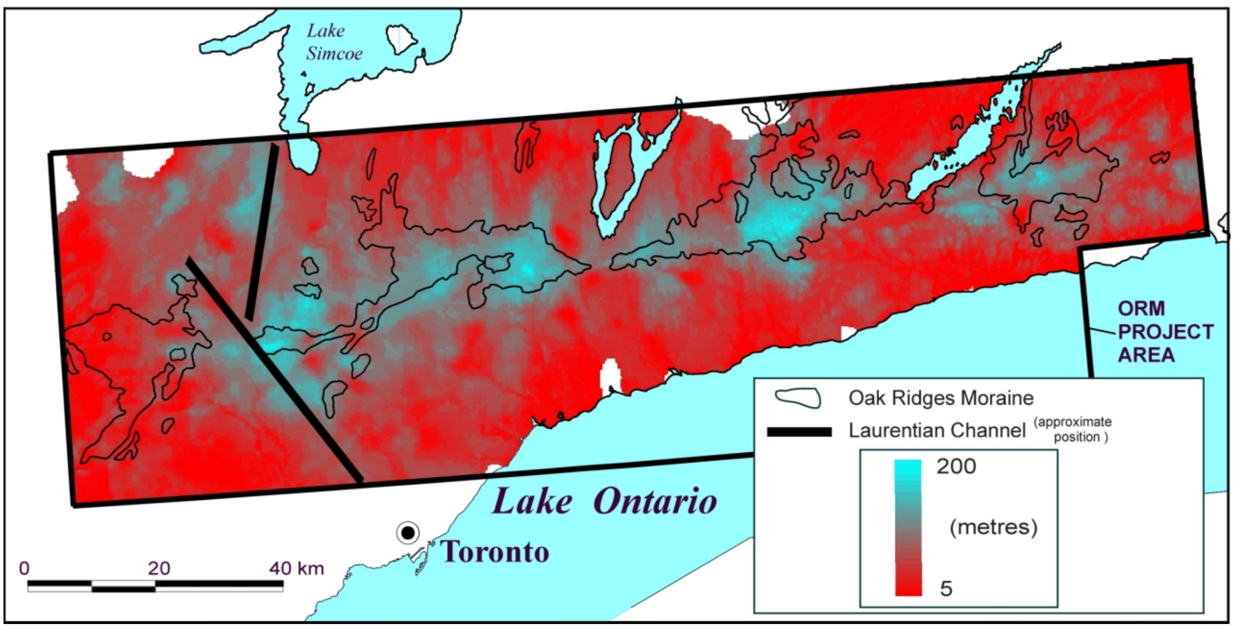

Figure 4. *Drift thickness map of the Oak Ridges Moraine (ORM) study area*

GIS layers

Information in this category includes both archival data (e.g. original Landsat TM) and thematic data layers (e.g. interpreted TM, geology). As the project progresses, the number of thematic layers will increase as data is interpreted and interpolated from point to spatial data sets (e.g. field points via airphoto interpretation to surface geology maps) (Fig. 3). A hydrologically sound 1:50 000 scale DEM with a 30 m grid resolution is being developed with the assistance of the Ontario Provincial Remote Sensing Office (Kenny et al., 1996; Skinner and Moore, in press) (Fig. 1). This DEM will provide an elevation datum for project data, permit landform analysis, and aid watershed mapping. To supplement sparse bedrock elevation data beneath the moraine, a regional gravity survey has been completed along the road system with station intervals of 500 m (east-west) and 3-4 km line spacing (north-south) (~3000 stations).

Landsat TM coverage of the study area supplemented by partial SPOT, ERS-1, and RADARSAT data coverage has been obtained (Table 2). These data are proving to be invaluable for terrain analysis, wetland, and landcover mapping. A thermal image flown along the south side of the Oak Ridges Moraine by PRSO has been incorporated into the database. These data highlight open water on a cold (-20°C) March night in 1994 and are providing insights concerning spring locations and related geological correlations.

Flat file layers

Extensive geophysical surveys have been conducted to define the 3-D sediment architecture and hydrostratigraphy (Table 3) (Pullan et al., 1994). For regional analysis the reflection seismic data has proven key to understanding the stratigraphic succession (Sharpe et al., 1996). The ground penetrating radar data has provided information on sediment architecture and depth to the water table. The borehole geophysics (borehole seismic, gamma, magnetic susceptibility, and conductivity) have provided valuable data for reflection seismic correlations and sediment property characterization.

All geophysical survey locations have been entered in the header table of the relational database and flagged appropriately. Selected vertical measurements have been taken from interpreted seismic profiles and entered as interpreted seismic logs. Reflection seismic profiles and ground penetrating radar are also captured as TIF images and can be used as a backdrop when plotting database borehole queries.

AN EXAMPLE OF A REGIONAL DATABASE MANAGEMENT SYSTEM QUERY AND GIS OPERATION

The Oak Ridges Moraine database is being used primarily to define the 3-D geometry of sedimentary deposits in the study area. This involves the formulation of selected queries of the relational database, and data interpolation and integration in a GIS. The following example demonstrates the combined use of an integrated database/GIS analysis. Production of a sediment thickness map of the study area requires delineation of two surfaces: the underlying bedrock surface and the landscape topography. Using the DEM as a reference, the surface elevations of all boreholes were standardized. The bedrock surface was defined using a database query to select the points to bedrock, and then interpolated within a GIS to produce a surface. The landscape surface is defined by the DEM (Skinner and Moore, in press). A common grid cell resolution was defined for the two surfaces, in this case the 30 m grid size of the DEM. The drift thickness map was then generated from the elevation difference between the two surfaces. The resulting map is a derivative surface of the previous two surfaces and highlights thick drift along the moraine and in the vicinity of the Laurentian Channel (Fig. 4). The strong correlation in the drift thickness and surface topography reflects the small number of original points to bedrock (~12 000) and resultant low resolution image of the bedrock surface.

FUTURE WORK

Work is ongoing with respect to data entry and verification. Data entry is approximately 90% complete: additional archival data are being added as it becomes available. During the course of preliminary data analysis (Hunter, 1996, pers. comm.) it has become apparent that the MOEE data set has between 20 and 30% location errors. The project is in the process of completing a systematic verification of locations for the MOEE data. A level of data verification for subsequent users is being incorporated by flagging duplicate locations, ambiguous sediment descriptions, and inconsistent data reporting.

It is anticipated that components of the database will be released in both digital (CD-ROM) and hardcopy formats as appropriate. The proprietary nature of some of the data will influence which data are released. Final formats have not been determined for CD-ROM releases but will probably include runtime viewing software for both the relational database and GIS data layers.

CONCLUSION

The choice of PC/Windows platform and software has proven to be a functional option for the scope of this project. The database has been able to provide complex data processing and querying abilities in a variety of formats along with network sharing functionality. MapInfo with Vertical Mapper has proven to be a low-cost solution for most of the map production and analysis needs. Some of the more intensive image processing and analysis have needed to be done with ArcInfo and PCI, but for the display and integration of these images MapInfo has proven suitable.

The ability to obtain archival data from a broad range of agencies working in the Toronto area has allowed the project to focus on specific geographic areas and hydrogeological and geological problems. This has permitted the optimization of scarce funds and minimized duplication of research efforts.

Queries on the database and GIS operations completed to date have demonstrated the functionality of the database (D.R. Sharpe, M. Hinton, L.D. Dyke, S.E. Pullan, T.A. Brennard, H.A.J. Russell, C. Logan, and A. Morre, 1995: poster presented at 1995 Ontario Mines and Minerals Symposium, Toronto, Ontario). Data analysis is starting to progress from local high quality sources and conceptual model development to the regional testing of models. The database will be an invaluable component of GIS analysis as an attempt is made to map the subsurface geology with the same rigor commonly applied to regional surface mapping.

The range of geoscience data in the database makes it of interest to a broad spectrum of users in the Greater Toronto Area. Consultants and municipalities in the area have shown an interest in the database and its release to the public. Subsurface components are useful to hydrogeologist, geochemistry to environmental agencies, and surface geology mapping to planners and agriculture. The DEM and some of the remote sensing and thematic map products can be used in applications involving architecture, engineering, land management, recreational planning, fisheries management, hydrology, hydrogeology, geology, and agriculture.

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