

Not Without Sedimentology: Guiding Groundwater Studies in the Oak Ridges Moraine, Southern Ontario¹

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The Oak Ridges Moraine (ORM) area in southern Ontario is an ~11,000 km² region that houses the largest urban population in Canada (Fig. 1). Groundwater continues to be an important resource, not only for rural households, but also a number of small cities (e.g., Newmarket), agriculture and recreation. Prior to 1993, regional municipalities, government agencies and industry had completed numerous site-specific studies but no regional framework existed within which these local studies could be integrated. A regional geological - hydrogeological study was initiated by the Geological Survey of Canada to establish a 3-D stratigraphic and hydrostratigraphic framework. A basin analysis methodology involving sedimentology, geophysics and hydrogeology was adopted. Sedimentological models were used to improve geological understanding of the area in the following ways: i) stratigraphic architecture, ii) material and stratigraphic coding of archival data, iii) event sequence concepts, iv) depositional facies models.

A conceptual model of the stratigraphic architecture was developed based on regional knowledge and current understanding of glacial processes (Sharpe et al. 1996). This model was used as a working hypothesis that was tested through geological mapping, drilling, seismic reflection profiling and sedimentology. Integration of archival water well, geotechnical and hydrogeological data was an objective of the study due to the abundance of these data and their common use by consultants. Low reliability of primary descriptions, poor resolution of individual units, and lack of sedimentological information were common problems with archival data (Fig. 2). A particular problem was the absence of descriptions of diamicton (till) in the ~50,000 water well records. In contrast regional mapping indicated that ~22 % of the area had diamicton exposed at the surface. To facilitate integration of these disparate archival datasets and improve the geological integrity a common coding scheme was developed (Russell et al. 1998). Two recoding techniques, First Attribute Method (FAM) and a Rule Based Method (RBM) were applied. FAM uses only the first of three attributes whereas RBM uses all three attributes and integrates sedimentological knowledge of the basin. The integrity of the coding system was tested by comparison of the first unit in archival borehole data with the surficial geology map (Fig. 3). The RBM performed more convincingly than FAM in all integrity checks.

¹Contribution to the Oak Ridges Moraine NATMAP project

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The sedimentological data was then used to constrain stratigraphic coding of ~25,000 archival data points. Regional stratigraphic surfaces were then interpolated within a GIS (Logan et al. 2001). The composition of the Oak Ridges Moraine was assessed using the archival and sediment facies data (Fig. 4). In common with field experience, this comparison indicates that archival data over-report fine-grained sediment, often by an order of magnitude (Fig. 4a). Comparison of estimates from continuous core with water well data indicates that clay is over estimated by ~30% - at the expense of fine sand. Such erroneous reporting has serious implications when considering aquifer yield or when mapping aquifer vulnerability.

Using sedimentology knowledge a depositional model of the moraine was developed that defined the spatial and stratigraphic relationships of the moraine and tunnel channel fills. This model defines significant differences in fill geometry and sediment facies compared to more traditional and broadly described alluvial valley-fill succession. A subaqueous fan depositional model is one depositional element of the ORM that permits estimates of flow unit distribution, geometry and thickness at a more detailed scale (Fig. 5).

Conceptual geological models of stratigraphic architecture and depositional facies can provide regional groundwater studies with much needed control and guidance toward development of improved hydrostratigraphic models, understanding of spatial heterogeneity, and improved predictive ability.

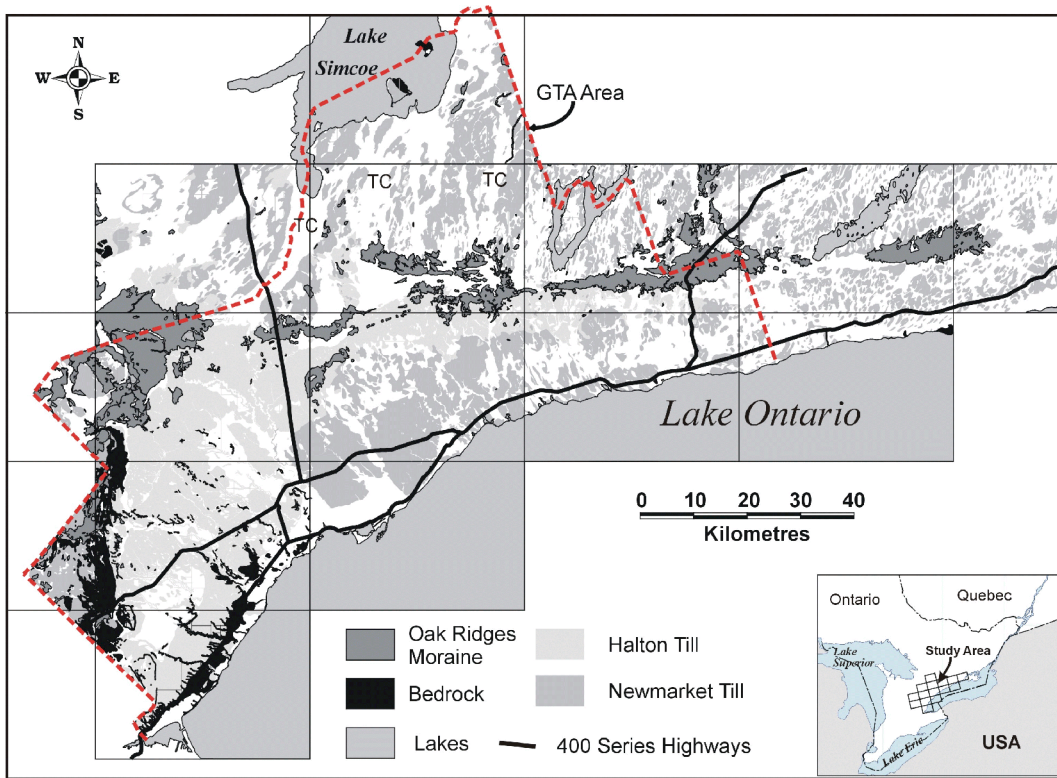
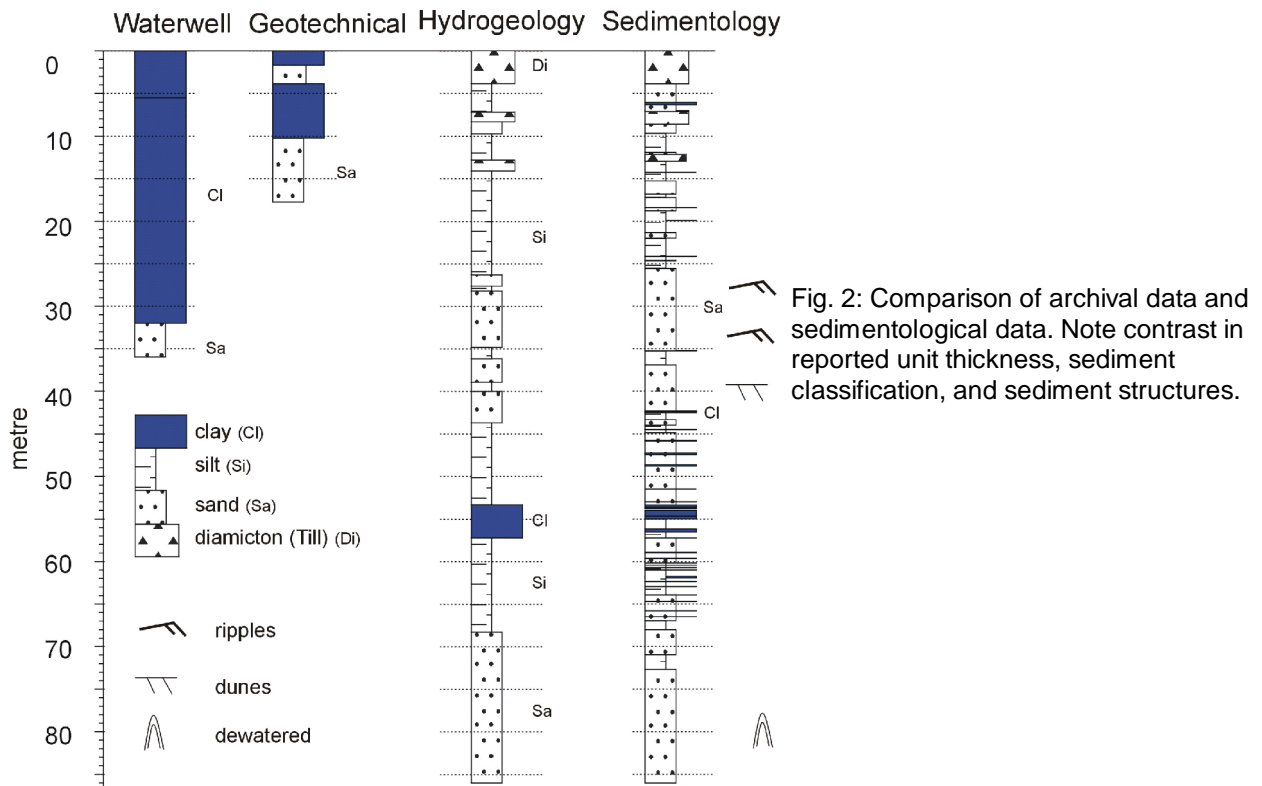


Fig.1: Location of the Oak Ridges Moraine study area in southern Ontario (inset). Generalized geology of the area. Oak Ridges Moraine extends ~160 km from east to west. Note tunnel channels north of the moraine (TC) that show up as white north-south corridors between areas of Newmarket Till.



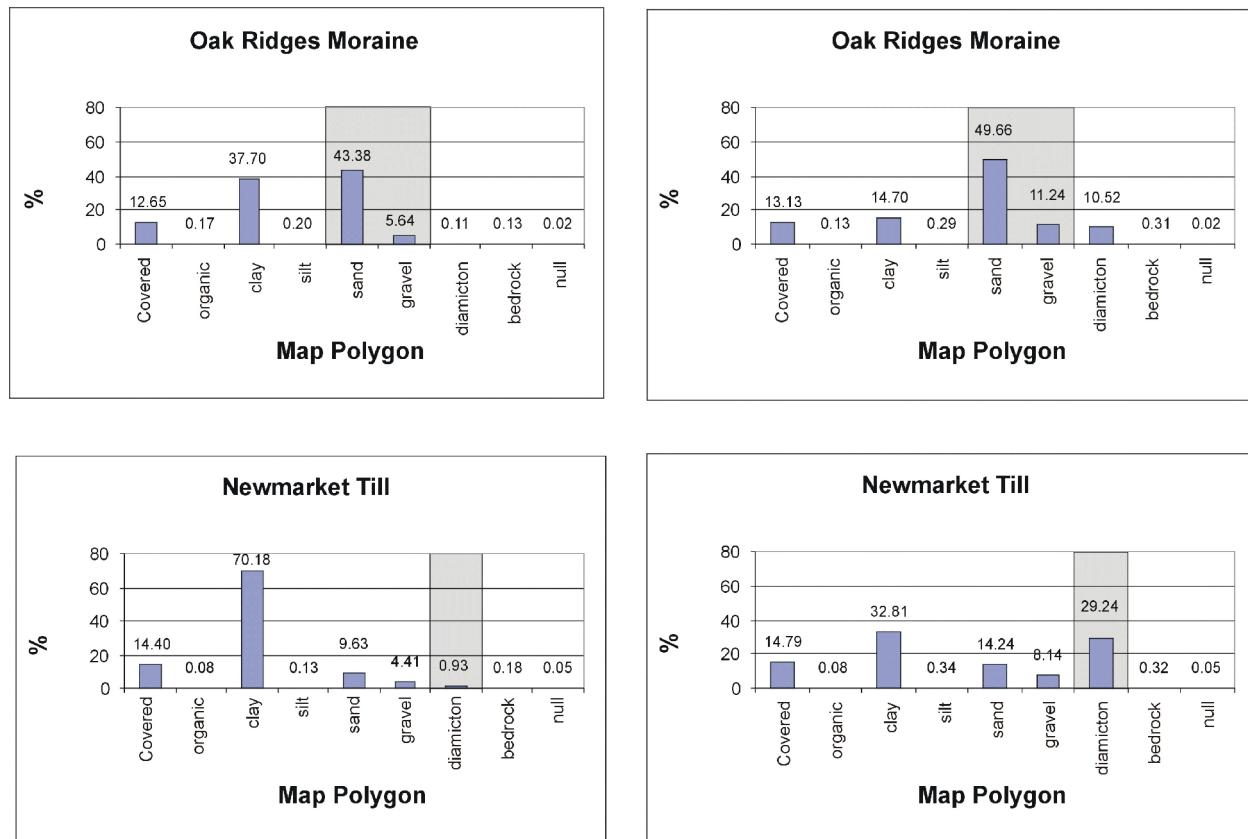


Fig. 3: Comparison of two methods of coding archival water well data with the surficial geology, left column is FAM, right column is RBM. Grey band indicates material that best matches the surficial geology unit. Note the high percentage of reported clay. Modified from Russell et al. 1998.

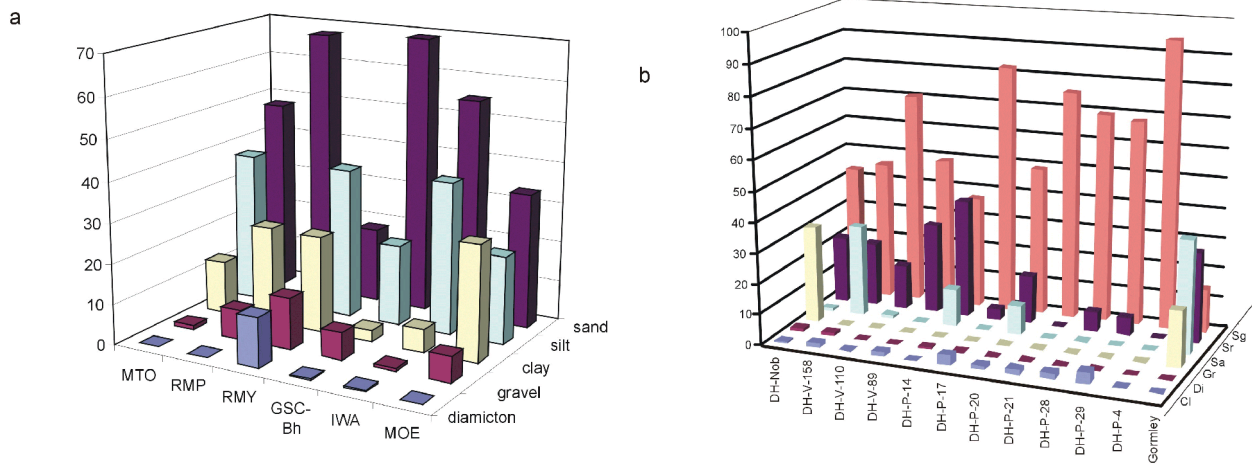


Fig. 4: (a) Comparison of composition of Oak Ridges Moraine based on archival data sets and GSC data. (b) Moraine composition using sediment facies coding for continuous core and outcrop sections. MTO - Ministry Transport Ontario (geotechnical); RMP- Regional Municipality of Peel, RMY- Regional Municipality York, IWA - Interim Waste Authority, (hydrogeology); GSC - Geological Survey of Canada (sedimentology); MOE - Ministry of Environment water wells. Sg - graded fine sand - silt, Sr - ripple scale cross-laminated sand, Sa - dune scale cross-stratified sand, Gr - gravel, Di - diamiction, Cl - clay (From Russell, 2001).

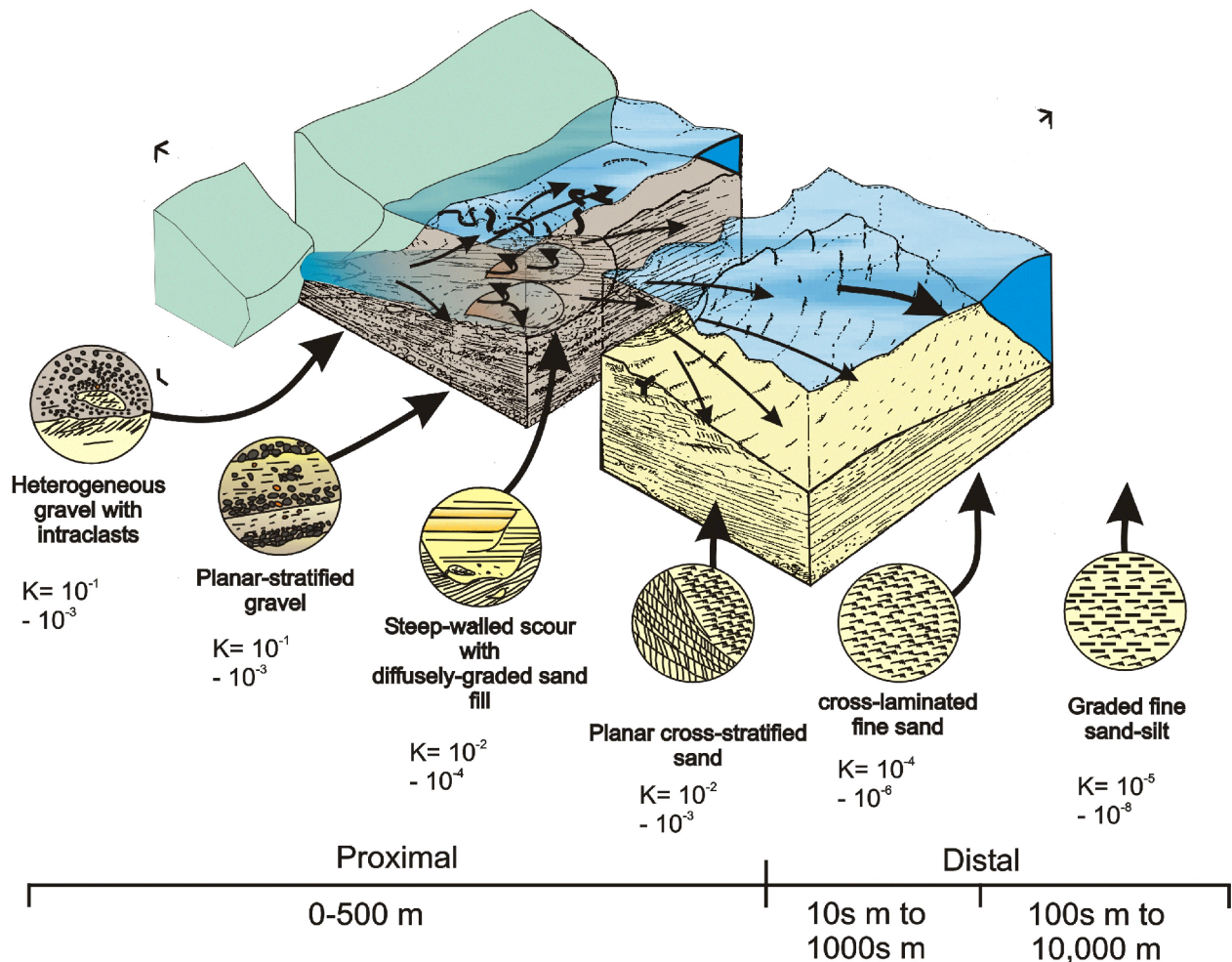


Fig. 5: Depositional model of a subaqueous fan element of the Oak Ridges Moraine. Note, rapid streamwise facies changes from gravel to fine sand; inset figures of major sediment facies; K values (m s^{-1}) are general ranges from Freeze and Cherry (1979). Model is modified from Russell, 2001.

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